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Spectrum Usage for the Fixed Services

Robert J. Matheson

U.S. DEPARTMENT OF COMMERCE
William M. Daley, Secretary

Gregory L. Rohde, Assistant Secretary
for Communications and Information

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ABBREVIATIONS

ADSL	Asymmetric digital subscriber line
ATC	Air traffic control
AMSC	American Mobile Satellite Corporation
BAS	Broadcast auxiliary service - used by broadcasters to move signals between facilities
BETRS	Basic exchange telecommunications radio service (telephone service via fixed radio link)
BSS	Broadcast satellite service - high power satellite TV broadcasting (same as DBS)
CAP	Competitive access provider - provides telecom services to business and homes
CARS	Cable relay system - a radio service used to bring TV signals to cable systems
CATV	Cable TV or (same thing) Community Antenna TV - public distribution of TV via cable
CLEC	Competitive local exchange carrier (competition for the local phone company)
DBS	Direct broadcast satellite - high power satellite TV broadcasting
DCTN	Defense Commercial Telecommunications Network
DECCO	Defense Commercial Communications Office (part of DISA)
DEMS	Digital electronic message service
DISA	Defense Information Systems Agency
DoA	Department of Agriculture
DoD	Department of Defense
DoE	Department of Energy
DoI	Department of Interior
DoJ	Department of Justice
DS-1	Industry standard equivalent to 1.5 Mb/s or 24 voice circuits
DS-3	Industry standard equivalent to 45 Mb/s or 28 DS-1
DTV	Digital TV - includes various standards, like HDTV and various lower resolutions.
EMC	Electromagnetic compatibility
ENG	Electronic news gathering - temporary BAS TV link used for remote news coverage
FCC	Federal Communications Commission
FTS 2000	Umbrella contract for Government procurement of commercial telecom services
GaAs	Gallium Arsenide - substrate material used for microwave electronics
GMF	Government Master File - database containing Government radio assignments
GWCS	General wireless communications service
GPS	Global Positioning System - satellite system providing accurate position information
HDFS	High density fixed service
HDTV	High-definition television
ICR	Inter-city relay - BAS link carrying TV between and within cities
ILEC	Incumbent local exchange carrier
ISDN	Integrated services digital network- telephone system with all services carried digitally
ISM	Industrial, scientific, medical - a noncommunication service that requires no license

ABBREVIATIONS (Continued)

ITFS	Instructional TV Fixed service - TV used to provide classroom instruction
IXC	Inter-exchance carrier - long distance telephone company
LEC	Local exchange carrier - the local telephone company
LMDS	Local multipoint distribution system - (28 GHz cellular cable)
LMR	Land mobile radio
MAS	Multiple address system - a point-to-multipoint system
MDS	Multipoint distribution system - an earlier 2-channel version of wireless cable
MDU	Multiple dwelling unit - apartments, hotels, condominiums, etc
MMDS	Multichannel multipoint distribution system - new 33-channel wireless cable
MMIC	Monolithic microwave integrated circuit
MSO	Multiple system operator - a company that operates many cable systems
NG	non-Government assignment or license - administered by the FCC
NOI	Notice of inquiry
NPRM	Notice of proposed rulemaking
NTSC	National Television Standards Committee - the technical standards used for analog TV
PCS	Personal communication services - family of cellular-like digital short-range communications
PSN	Public switched network - the network encompassing the whole telephone system
OC-1	Industry standard for optical fiber communications, equivalent to a DS-3 or 45 Mb/s
OC-N	Industry standard for optical fiber communications, equivalent to N DS-3s or N x 45 Mb/s
QAM	Quadrature amplitude modulation - amplitude and phase modulation for digital systems
RBOC	Regional Bell operating company - any of the eight regional telephone holding companies
RDTE	Research, development, testing, and evaluation
SCADA	Supervisory control and data acquisition - monitor/control of pipelines, railroads, etc.
SHL	Studio to headend link - CARS link carrying programs from central hub to cable headends
SMA	Small master antenna - similar to CATV, but serving one complex (e.g., hotel or condo)
SMR	Specialized mobile radio - a commercial (trunked) mobile radio service
SNG	Satellite news gathering - relay of local news coverage from remote site via satellite
SONET	Synchronous optical network - telecommunications standard for optical fiber systems
STL	Studio-to-transmitter link - a link carrying program material from the studio to the transmitter
TDRSS	Tracking and data relay satellite system
TIA	Telecommunications Industry Association
TSL	Transmitter-to-studio link - a link carrying program and/or transmitter status to the studio
TVRO	TV receive-only - a satellite terminal whose only function is to receive TV signals
VA	Department of Veterans Affairs
VSAT	Very small aperture terminal - a low capacity two-way satellite system using small antennas
VTS	Vessel Traffic Service - Coast Guard control system for ships in harbor areas

ABBREVIATIONS (Continued)

WCS	Wireless communications service - the set of rules applying to the 2.3 GHz band.
WDM	Wavelength division multiplexing - carrying multiple optical carriers on a single fiber
WLAN	Wireless local area network
WLL	Wireless local loop (radio replacement of telephone wires leading to a house or business)
xDSL	Various versions of DSL (digital subscriber line) providing several Mb/s with telephone lines

EXECUTIVE SUMMARY

This report is an update of a 1993 NTIA staff study "A preliminary look at spectrum requirements for the fixed services." The 1993 study examined 30 frequency bands used for fixed services, including historical license data, and market and technology factors that would be expected to cause the use of these bands to grow or diminish. The fixed service bands are used chiefly to provide point-to-point microwave services, a market which is arguably dominated to an increasing extent by optical fiber. A major objective of this report is to provide current information and insight regarding the degree to which the existing fixed service bands will continue to be needed for their allocated services.

This report discusses each of the 30 bands individually, including several types of service. The common carrier service (also called public service) furnishes communication services to the public-at-large. Local and long distance telephone companies are typical examples of common carriers. Private operational service provides internal communications for the operators of the service. Private services are used to control gas pipelines and electric powerline networks, to coordinate local government activities, and to tie together a corporation's several operating locations. The broadcast auxiliary service is used by broadcasters to distribute programs within a broadcaster's operations, e.g., to transfer a TV program between the studio and a mountaintop transmitter site. Cable TV relay service and private cable relay service are used to transfer large numbers of TV channels to cable headend sites and large hotel and apartment complexes. The Federal Government uses fixed services to provide a myriad of defense and non-defense functions in locations and circumstances where commercial communication services do not satisfy requirements.

Common carrier licenses reached a peak of 78,000 licenses in 1988 and have slightly decreased since then (76,000 licenses in 1997). While optical fiber has replaced many of the long-distance high-capacity microwave networks, shorter-range microwave systems supporting rapidly expanding cellular and PCS networks have proliferated. Recently, however, the number of new microwave links has not been keeping up with the number of new cellular/PCS sites. This indicates less use of microwave to connect cellular/PCS sites, but it also may indicate that many sites are being connected using frequencies that are not individually licensed. Many microwave links have moved from the 4 GHz band to the 6 GHz band, because of difficulty sharing with satellite downlinks in the 4 GHz band. Rapid growth continues in the 10.5 GHz and 18 GHz bands, mainly in support of cellular and PCS sites. Earlier rapid growth in the 2 GHz band has reversed, as new band allocations will soon require moving these links to another frequency band. Common carrier licenses increased by 1.1% annually over the last 5 years; they are projected to increase by 1% per year for the next 5 years.

The number of licenses for private operational services reached a peak of 53,000 in 1994 and have slowly decreased since then (50,000 licenses in 1997). Users in the 1.9 GHz band were moved to other bands (mostly the 6.5 GHz and 23 GHz bands) to make room for new PCS systems. Private operational services (not counting private cable) grew by 0.3% annually over the last 5 years; they are expected to remain constant at their present levels for the next 5 years.

Broadcast auxiliary service (BAS) licenses have grown steadily and rapidly (10% a year), reaching 8500 licenses in 1997. The switch to digital TV in the next few years may substantially change the way that broadcasters use BAS, since additional TV channels will be created (increasing the BAS support needed), but this may also be an opportunity to change many older BAS systems to fiber. In addition, the FCC is proposing to reallocate the 1990-2110 MHz BAS band, requiring the broadcasters to purchase new equipment to fit within the channels in the new allocation. All of this creates considerable uncertainty in the number of BAS licenses that will be used in the near future. BAS licenses grew at an average annual rate of 9.5% over the past five years; they are expected to grow at a 5% annual rate over the next 5 years.

Cable TV relay services (CARS) and private cable relay services are used to distribute large blocks of TV channels to cable TV systems or to private networks serving hotels and apartment buildings, respectively. Although the two services are technically quite similar, they operate under different regulations, which has led to different patterns of growth. CARS grew rapidly to 123,000 licenses in 1994, but have decreased slightly since then. Many current CARS licenses are believed to be unused now, since many cable TV owners have upgraded their cable systems to carry 2-way digital data. The upgrade typically uses two-way optical fiber to replace many of the old one-way CARS links. The number of CARS licenses in use is expected to decrease at a 5% annual rate over the next 5 years, though license holders have been reluctant to return the unused licenses in the past.

Private cable relay services have grown very rapidly in the last 7 years (from almost nothing to 85,000 licenses), and they are still growing rapidly. Private cable operators, however, are prohibited from owning wide-area fiber systems, so private cable will remain much more dependent on microwave services. Private cable microwave licenses are expected to increase at a 10% annual rate for the next several years. Private cable may stop growing within 5 years, as it faces competition from new wireless services and other competitors.

The Federal Government uses microwave point-to-point services for control and monitoring of many wide-area systems, like air traffic control, gas pipelines and electric power service, for connecting Federal mobile radio sites, for tactical communications, and for communications within test and training ranges. Over the past 5 years, the number of fixed Federal frequency assignments has increased about 1% per year, resulting in 31,000 fixed service assignments in 1997. Federal fixed assignments are expected to remain constant over the next five years.

Altogether, total U.S. fixed microwave use (industry and government) reached a peak of about 165,000 licenses and assignments in 1996. (This count does not include CARS or private cable service.) It has decreased very slightly since then. The total count is expected to remain approximately constant over the next 5 years.

Several other general trends have been observed. There has been a movement away from the lower frequency bands (below 5 GHz) and into the higher frequency bands (up to 39 GHz). This has been driven partly by the reallocation of some lower frequency bands (e.g., 2 GHz) for new non-fixed applications, partly by the recent functional availability of some new higher frequency bands, and partly by the nature of some new fixed service applications.

There has been a recent trend toward microwave links that do not need to be individually licensed. This includes Part 15 transmitters operating in several industrial, scientific, and medical (ISM) bands, the 5 GHz unlicensed national information infrastructure (U-NII) bands, and many new bands that are licensed by geographical area. Since this report has keyed user growth to the number of licenses, the increasing use of transmitters that are not licensed individually may cause much user growth to be hidden from the data-gathering processes used in this report. The addition of unlicensed transmitters to the reported license counts might convert the present, apparently stagnant, industry growth patterns to a much healthier 2-5% annual growth rate. However, most of the actual “unlicensed” counts are not available, and therefore growth estimates based on them are currently mere speculation. One U.S. manufacturer of Part 15 systems claims 20,000 radios installed. The trend toward unlicensed transmitters is expected to become even stronger in the future.

Finally, the nature of fixed microwave applications is changing. Whereas past microwave systems were used to support a system's widest bandwidth "pipes," now there are many applications where only optical fiber can reasonably support the widest bandwidths. Therefore, many microwave applications are shifting toward "access" applications–the means by which individual users are connected to a local fiber-based communications infrastructure. This change will greatly increase the number of microwave systems in use and will move them much closer to the typical users. Possibly some of these systems will even become sufficiently numerous and inexpensive to be correctly termed "consumer" systems. Whether they are consumer products or not, many of these systems will not be individually licensed.

In summary, the future growth of the microwave industry and the fixed service frequency bands used by that industry will be largely dependent on how narrowly one defines "the industry." Traditional point-to-point microwave applications are barely holding their own and will be expected to slowly diminish in the future. On the other hand, new "access" applications–especially at higher frequencies–are expected to require the massive deployment of microwave communication systems in many frequency bands.

Spectrum Usage for the Fixed Services

Robert J. Matheson[1]

This study is an update to a 1993 ITS staff study entitled "A preliminary look at spectrum requirements for the Fixed Services." That study included a description of the services provided in 30 of the Government and non-Government frequency bands between 406 MHz and 30 GHz known as point-to-point terrestrial microwave bands. Each of the 30 frequency bands were described in terms of the services provided, growth of licenses, and the geographical distribution of current licenses. The technical, regulatory, and economic factors affecting each band and the total microwave market were described, as well as a prediction of the rate of future growth (or decrease) for each band and market segment. This study adds 6 more years of license information and updates much data on recent regulatory and market trends. Some of the general technology and market descriptions have been left out of this update, but earlier predictions are compared to actual market performance and revised forecasts are made.

Keywords: fiber optics, fixed radio services, frequency allocation, frequency assignment, future spectrum requirements, microwave radio, spectrum crowding, spectrum management, telecommunications

1. UPDATE OF RECENT HISTORY IN MICROWAVE USAGE

1.1 Introduction

This publication is intended as an update to a 1993 ITS staff study on the fixed services.[2] About 30 frequency bands having primary allocations to the fixed services are described here, including the current applications for each band, a geographical distribution of current systems, statistical user information, and predictions for growth over the next 5 years. These predictions are based on analyses of technology and market factors and the current regulatory environment; they should not be construed to imply any special insights into future spectrum management policies. This update includes 6 years of additional user license information for each of the reported frequency bands; it also includes information on significant recent changes in the use of the bands. As an update, this report omits much basic unchanged information about the use of fixed services that was contained in the original staff study. In addition, some of the information in this report has not been updated, but it remains identical to that contained in the original staff study.

A major function of the 1993 staff study (and of this report) was to predict the future requirements for fixed service spectrum bands. Several decades ago, the fixed services were seen as the most likely technology to provide long-range transport of wideband digital, voice, and TV signals. Transcontinental chains of microwave relay stations were constructed, and a large number of frequency bands were

[1]The author is with the Institute for Telecommunication Sciences, National Telecommunications and Information Administration, U.S. Department of Commerce, Boulder, CO 80303

[2]R. J. Matheson and F. K. Steele, “A preliminary look at spectrum requirements for the fixed services,” ITS Staff Study, May 1993.

allocated to the microwave fixed services. Fully half of the allocated spectrum bands were allocated on a primary basis to the fixed services. Although these allocations were surely justified at that time, there have been substantial changes in technology and markets since then. Today, optical fiber carries the vast majority of broadband long-range communications. In addition, other advances in technology have made practical a greatly expanded set of wireless communication services. These potential new services require frequency bands in which to operate. An obvious question for spectrum managers is whether the use of optical fiber has displaced the use of microwave fixed services to the extent that some of the fixed service bands could be reallocated to some of the new wireless services. This question has already been answered in the affirmative for the 1.9 GHz and 2.1 GHz fixed service bands, which have recently been reallocated to PCS and other Emerging Technology services.

Some major trends have developed in the past several years, including a sudden growth in some fixed common carrier bands which was fueled by the need to interconnect many new cellular/PCS sites. The long-haul fixed services continue to face severe competition from optical fiber, to the extent that traditional high-capacity fixed services are generally not expected to grow. On the other hand, several new microwave applications for high-density fixed systems and non-licensed fixed services have the potential to grow rapidly. In addition to reallocating some of the fixed bands near 2 GHz to PCS applications, the Federal Communications Commission (FCC) has recently modified the allocations of many microwave bands to allow sharing between private and common carrier users and has provided more narrow-bandwidth channelization. The Federal Government has transferred several Federal bands (including some fixed service bands) to the FCC for reallocation to commercial services. These recent trends will be discussed generally, in addition to specific references in the descriptions of individual frequency bands.

1.2 Cellular/PCS Growth

As indicated in the original report, many cellular sites have been connected with microwave links. In most of these cases, microwave was selected over fiber or copper because of the ability to rapidly and conveniently install microwave vs. the delays and expense associated with cabling between cellular sites. Table 1.2 shows the number of non-cellular/PCS common carrier licenses, licenses for cellular/PCS providers, and the number of cellular/PCS sites, according to Cellular Telephone Industry Association (CTIA) statistics.[3]

Table 1.2. Cellular/PCS Licenses and Sites

YEAR (December)	**Common Carrier Licenses**	**Cellular/PCS number of Licenses**	**Cellular/PCS number of Sites**
1994	64008	11797	17920
1995	59011	13521	22663
1996	59203	14911	30045
1997	59979	14780	51600

[3]Cellular/PCS data from CTIA website statistics, January 4, 1999. (view_98datasurvey1.gif at www.wow-com.com)

About 21,000 cellular/PCS sites were added in 1997, giving a total of nearly 52,000 sites. Several years ago we believed that 70% of new cellular sites were connected with microwave links in the 2 GHz, 6 GHz, 11 GHz, or 18 GHz bands, requiring new licenses for about two microwave links per site. Assuming the same 70% using microwaves, 29,400 new licenses (21,000 sites x 2 links/site x 70% of sites) would have been issued in 1997 to support the additional cellular sites. Moreover, increased traffic within the whole cellular system would have required an increase in capacity for many of the internal microwave network links. Similar calculations would imply that about 71,000 microwave links would be needed to support the total number of 51,000 cellular/PCS telephone sites.

License data for December 1997 shows a total of about 15,000 microwave licenses in use by cellular companies, out of a total of 75,000 common carrier licenses. Both of these numbers were essentially unchanged from the previous year. These numbers probably underestimate the number of common carrier licenses used to support cellular/PCS, since microwave links embedded in the public switched telephone network (PSTN) or private companies (but used to support cellular systems) were probably not counted as cellular. Nevertheless, it is clear that the cellular/PCS industry is no longer installing new licensed microwave links at a rate proportional to the growth of new sites.

In spite of the 1997 installation of 21,000 additional cellular/PCS sites, there was no net increase in the number of licensed cellular/PCS-associated microwave links. Therefore, while the number of cellular/PCS sites will continue to grow, it does not seem to follow that this growth will appreciably increase the number of licensed microwave links. This major change from earlier cellular/PCS growth trends is caused by several factors. Many cellular/PCS systems are using non-licensed Part 15 spread spectrum point-to-point equipment in the 2.4 GHz or 5.8 GHz ISM bands or are using point-to-point services in bands that are geographically licensed (e.g., the 39 GHz band). Recently developed “pair-gain” technologies allow the transport of DS1 signals (1.54 Mb/s or 24 voice circuits) over distances of several miles using ordinary twisted pair copper telephone wires. Such technology will often be adequate to connect many single sites in urban areas. Broader bandwidths to connect multiple sites are often available (especially in urban areas) from multiple fiber providers, including LECs, CLECs, cable TV companies, and independent fiber providers. Finally, microwave is often used only temporarily, until other alternatives (such as those described above) become available. Thus, even while many new microwave links may be used every year to establish new sites, other microwave links are being removed equally rapidly from older sites.

In addition, extensive use of large microwave antennas at new cell sites may cause or exacerbate public objections to such sites. Whether this public attitude will continue to discourage the use of microwave links in future systems (e.g., high density fixed service systems, Section 1.5) is unknown. However, it may cause system planners to use higher frequency fixed service bands (which can use smaller antennas) or non-microwave alternatives.

1.3 Deployment of Optical Fiber

The deployment of optical fiber continues at a rapid rate. Figure 1.3 summarizes fiber deployment by the major telecommunication providers [1]. Although the IXCs, LECs, and CAPs are probably the largest fiber users, there has also been heavy activity by cable TV systems (not shown here), which consumed 34% of fiber purchased in 1996 [2]. Since typical fiber cables contain 20-50 fibers, the actual route mileage of deployed fiber cable is only 2-5% of the fiber mileage. Fiber still connects buildings in a relatively small percentage of geographical areas, even within large urban centers, and microwave links still remain very useful for interconnecting cellular telephone sites and large businesses.

Figure 1.3 shows substantial growth in the total miles of installed fiber. In addition to the increased amount of fiber, the capacity of each fiber to carry data is increasing substantially. The typical maximum modulation rate for commercial fiber systems has increased to 2.4 Gb/s, which is a four-fold increase over the typical maximum rate 6 years ago. In addition, wavelength division multiplexing (WDM) allows multiple data streams to be carried on a single fiber at slightly different optical carrier frequencies. As many as 32 separate optical data streams can currently be carried on a single fiber in commercial systems. Experimental systems have demonstrated total single-fiber capacities of almost 3000 Gb/s. Finally, the usefulness of increased data rate and WDM can be augmented by using newly-available optical amplifiers, which can greatly extend the useful transmission distance of most optical fiber systems.

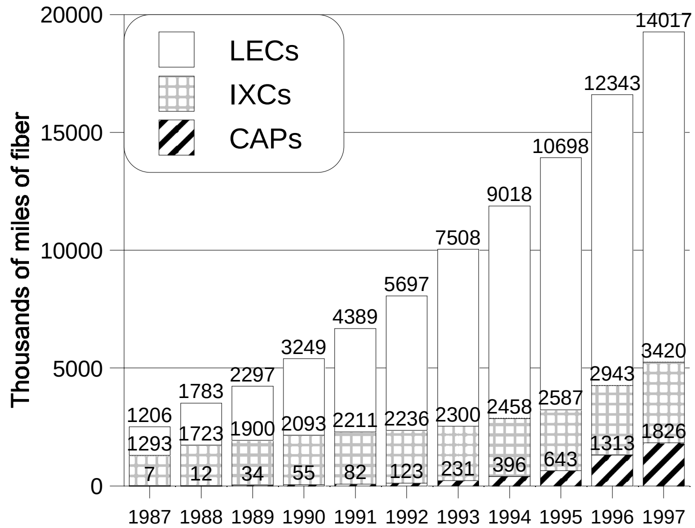

Figure 1.3. Thousands of miles of fiber deployed by IXCs, LECs, and CAPs (1987-1997).

The long-range, high-capacity systems that can be built with this new technology are especially applicable to rapidly growing transoceanic applications. For example, the TAT-14 cable (scheduled to begin operation in the year 2000 between the US and Europe) has a total capacity of 640 Gb/s, which is a 64-fold increase over TAT-13. This unprecedented increase in undersea fiber capacity should significantly lessen the need for some intercontinental fixed satellite systems.

Many strategies have been explored for greatly extending the reach of fiber throughout metropolitan areas. Cable TV companies and local telephone companies have experimented with various versions of fiber-to-the-curb (FTTC) and fiber-to-the-home (FTTH) systems. Local telephone companies are installing fiber-to-the-neighborhood systems (connecting central offices with neighborhood pedestals) and may greatly expand wideband xDSL systems. The widespread deployment of these systems could make wideband access more easily available, decreasing the number of microwave links needed to support future cellular and PCS deployments and wideband business access. However, none of the experimental FTTC or FTTH systems are assured of becoming widely available in the near future. The passage of the 1996 Telecommunications Act has partially clarified the rules under which cable TV and telephone companies are able to compete to supply fiber and other services. The resolution of these rules is expected to fuel a new round of competitive activity with major investments in the wideband fiber telecommunications infrastructure.

1.4 Fiber versus Microwave in Wide Bandwidth Future Applications

The relative bandwidth capacities of fiber and microwaves is changing. When optical fiber was first used commercially, it was extremely expensive and it had approximately the capacity of a single wideband microwave channel. A few years ago, the capacity of a single optical fiber had grown to equal the total capacity of a whole microwave frequency band. Today, a single fiber can carry communications equal to the whole usable radio frequency spectrum. Tomorrow, who knows? The significance of this trend is that microwaves and fiber are becoming less interchangeable, causing their fundamental communications roles to change. Whereas microwaves were once the most usable medium for “broadband” communications, there are now many fiber applications that require far too much bandwidth to be carried by a microwave link. Particularly in common carrier applications, where the communications of many users are combined into a single data stream, microwave will often not be able to support the bandwidth requirements. This will become more apparent as video and broadband Internet traffic increase the bandwidth requirements of typical users.

Thus, microwave links are being squeezed out of the high-bandwidth end of communications and out of certain applications in wider-bandwidth future communications architectures. Where the traditional telecommunication architectures used microwaves for long-haul and backbone (and wireline for customer access), new architectures will use fiber for long-haul and backbone–with microwave WLL, coax, and wireline for access. For example, a microwave link to a small remote community may become too limited in capacity, even if it were expanded ten-fold. Although microwave links once furnished the broadband backbone connecting central offices, in the future they will be useful only as a lower-capacity emergency back-up, useful if a major earthquake simultaneously severs all the fiber ring connections. What alternative media will be available to meet normal wideband traffic demands in the future, when the route traffic exceeds the capacity of existing microwave links?

Microwave technology will become increasingly useful for accessing individual users and narrow- and medium-bandwidth groups of users–replacing wireline or fitting into the bandwidth gap between wireline and fiber. We should expect to see more microwave applications for WLL, WLANs, and other new short-range access technologies. Many of these are non-traditional microwave applications, however, and they may not be as easily recognized as the traditional microwave fixed services of the past. The new applications will tend to move the microwave industry closer to the individual user and closer to the mass market. These short-range access markets will be particularly suitable for higher microwave frequency bands–where the smaller antenna size, greater frequency reuse, and wider available bandwidths provide major advantages.

1.5 High Density Fixed Systems

The traditional uses of point-to-point microwave have included high capacity “backbone” systems carrying multiple DS-3s (often using multiple hops to cover the long distances between large cities), “thin-route” systems (usually SCADA applications where alternative communications are often not available), and “quick reaction” circuits where microwave can be installed much faster than wireline circuits (e.g., interconnection of cellular sites or temporary connections for special events). High density fixed systems (HDFS) represent a new type of microwave deployment, which will play a major role alongside the three traditional roles described previously.

HDFS is characterized by a large number of short range, single-hop, microwave links to local hubs. Typically, the hubs would be interconnected with fiber, the microwave links would carry wideband digital (DS-1 to DS-3 capacity), and the short range would permit very high frequency reuse. The hubs might use a point-to-multipoint architecture (omnidirectional hub or segmented hub, directional user site antennas) or multiple individual point-to-point links terminating at each hub. Such systems would be particularly suitable for dense urban environments, using microwave bands above 20 GHz. The use of relatively high frequency bands permits small directional antennas, wide bandwidths, and short reuse distance. The fundamental premise of HDFS systems is that they would provide a cheaper means than optical fiber for connecting medium-bandwidth customers, for applications where the existing copper twisted-pair is not adequate. The typical customer might be a business or a home Internet user or a home TV viewer, though initial implementations would probably concentrate on office buildings, multiple dwelling units, and hotels.

No HDFS systems have been widely deployed yet, though some are beginning to offer initial services in multiple U.S. cities. Examples of emerging HDFS systems include Teligent's WLL at 24 GHz, LMDS at 28 GHz, Winstar's "wireless fiber" at 39 GHz, and the proposed"stratospheric repeater" near 50 GHz. It is too soon to predict which, if any, of the proposed HDFS systems will be commercially successful. Most of them would assume the role of a CLEC, competing with the local phone system, but additionally supplying broadband Internet access and (possibly) TV/video programming.

HDFS is a somewhat fuzzy category. For example, two-way MMDS experiments with two-way digital services might fit into HDFS, except for the much-lower 2.6-GHz MMDS frequency band. Similarly, one could envision a telephone central office directing a large number of conventional microwave links to specific large customers fitting the basic HDFS definition. The major reason for defining a specific official service category of HDFS–as distinguished from "fixed service (FS)–is that FS often shares frequency bands with satellite-based fixed services (FSS). Because of the very large number of HDFS terminals and the high cumulative transmitter power, many people believe that it would be impractical to allow sharing between HDFS and satellite services.

1.6 Unlicensed Spread Spectrum Systems in ISM and U-NII Bands

A number of companies are manufacturing spread spectrum systems that operate under Part 15 rules as unlicensed point-to-point radios in the 2.4-GHz and 5.8-GHz bands, which are also allocated to Part 18 ISM systems. These systems typically provide up to 1 or 2 T1 channels with 1-watt transmitter power. Although these unlicensed radios have no coordinated protection against interference, the combination of high gain directional antennas, spread spectrum modulation, and error correction usually provide adequate performance. About half of these radios are used to interconnect cellular/PCS sites. Although leakage from microwave ovens radiates noise across much of the 2.4-MHz band, this can usually be treated as an increase in background noise and compensated for in the system gain calculations.

These Part 15 radios have essentially created two new point-to-point microwave bands having very rapid growth. Although no licensing delays or cost apply to these radios, no protection against interference is implied or coordinated either. One manufacturer suggests that a useful strategy would be to install a 5.8 GHz unlicensed link and begin operation immediately, while simultaneously applying for a license for operation in the 6-GHz or 6.5-GHz licensed bands. When the 6-GHz license is issued several months later, the operator has some options. He can install a licensed radio on a permanent basis, perhaps moving the unlicensed radio to another new site where the cycle will be repeated. Since the licensed and unlicensed bands are quite close in frequency, no adjustments to the antennas or waveguides will usually be needed and minimum additional cost will be involved in the change-over. The operator could also choose to continue operation in the ISM band, with the option of switching to a licensed band if interference ever becomes a problem.

The use of the ISM bands for high reliability communications is problematic, mainly because there is no assurance that today's adequate performance will remain free of interference in the future. In general, one should expect very substantial growth in unlicensed systems of many types, e.g., cordless phones and

WLANs. Eventually there may be too many additional systems to expect interference-free operation in crowded locations. Or, maybe not. Another problem, from the standpoint of this report, is that the presence of these unlicensed radios does not show up in any license databases. One U.S. manufacturer claims 20,000 radios installed worldwide, mostly in the U.S. This single factor would cause a substantial under-reporting of growth in microwave usage, converting declining or plateaued usage into consistent growth.

The situation will be similar in the recently allocated "unlicensed national information infrastructure" (U-NII) band. This 5-GHz band with 300 MHz total bandwidth is designed especially to support wideband WLANs, but it also permits use of directional antennas for long range point-to-point services. Unlicensed systems with DS-3 capacity are available in the 5.8 GHz part of this band. As with other unlicensed applications, the possible growth of interference in this band due to uncoordinated use is a potential problem for which no one has sufficient experience to give a convincing answer yet.

1.7 Reallocation and Rechannelization in the 2 GHz Migration Bands

The FCC has reallocated 220 MHz of spectrum near 2 GHz from fixed services to emerging wireless technologies, especially PCS. A major part of the 1850-1990 MHz band was auctioned for PCS at the beginning of 1995, with the remainder auctioned by early 1997. The existing fixed private operations users in the 1850-1990 MHz band will be required to move out of this band, though their cost of relocating to another band will be reimbursed by the PCS operator. The spectrum changes required by this reallocation are evident beginning with 1996 license data. The 2110-2150 MHz and 2160-2200 MHz bands are also earmarked for reallocation, but the details are still under vigorous discussion and no definite date has been set for an auction or other reallocation procedures. This has given the cellular operators and private users in the 2110-2150 MHz and 2160-2200 MHz bands an extra year or two of operation and has encouraged the continued use of these bands to support new cellular telephone sites. The proposed requirement for satellite system operators to reimburse incumbents may further delay major changes in the use of these bands.

To ease the migration of microwave users from the reallocated 2 GHz bands to new fixed bands, many of the fixed bands at higher frequencies have been rechannelized to include narrower channels and reallocated to permit shared use by both common carrier and private users, as described in an FCC rulemaking FCC 93-350 [3]. The rechannelization of the bands was desirable, since the private operational users in the 1850-1990 MHz band and the private and cellular users in the 2110-2150 MHz and 2160-2200 MHz bands typically used relatively narrower bandwidths. In addition, the common carriers are now building most of their wideband capacity with optical fiber, and do not require as large a proportion of their spectrum to be channelized with 20-MHz, 30-MHz, and 40-MHz bandwidths. This gives private users access to the wider bandwidths available in the original common carrier bands. It also gives common carriers access to many more narrowband channels than were previously available to them, more efficiently matching the limited amount of traffic present at cellular/PCS sites.

Although the December 1997 license data used in this report does not yet completely show the effect of these allocation changes, frequency coordinators note many "cross-band" licenses (i.e., common carriers requesting licenses in bands that were previously limited to private operation, or vice versa).

The following bands are intended as migration bands for users displaced from the 2 GHz bands. The channelization bandwidths permitted in each band are indicated before and after the changes were made.

The channels described below represent overlapping alternative channelization plans; therefore, it would not be possible to simultaneously use all of the channels listed at a single location.

Using the 5925-6425 MHz band as an example: The notation of "24 pr" in the column headed “0.4 MHz” and the row headed “Now,” means that there are now 24 pairs of channels (48 channels in all), each channel having a 0.4 MHz bandwidth. The original channelization for this band is indicated in the “Was” row to have included only the 8 pairs of 30 MHz channels. Note that the indicated 24 pairs of 10 MHz channels or 8 pairs of 30 MHz channels would each occupy 480 MHz (out of the 500 MHz available in the band). Therefore, the 10 MHz and 30 MHz channelizations must overlap in much of the same part of the band. Some channelizations represent alternative, rather than simultaneous, uses of the frequencies.

a. 3700-4200 MHz band (was common carrier only).

Was: 20 MHz
Now: 20 MHz (no change)

In the 3700-4200 MHz band, terrestrial fixed links have problems sharing with fixed satellite downlinks. The existing fixed terrestrial links are leaving this band at a rapid rate, and the lack of any new narrowband channelization suggests that this band is likely to be relatively lightly used by terrestrial fixed systems in the future.

b. 5925-6425 MHz band (was common carrier only)

bandwidth (MHz)	0.4	0.8	1.6	1.25*	2.5*	3.75*	5.0*	10*	30*
Was:	---	---	---	---	---	---	---	---	8 pr
Now:	24 pr	12 pr	---	59 pr	29 pr	13 pr	12 pr	24 pr	8 pr

* These channels are submultiples of 29.65 MHz, instead of the indicated nominal 30 MHz.

c. 6525-6875 MHz band (was private operations only)

bandwidth (MHz)	0.4	0.8	1.6	1.25	2.5	3.75	5.0	10	30
Was:	---	6 pr	3 pr	---	---	---	15 pr	17 pr	---
Now:	12 pr	6 pr	---	132 pr	66 pr	31 pr	31 pr	17 pr	---

d. 10.55-10.68 GHz band (was private operations and common carrier)

bandwidth (MHz)	0.4	0.8	1.6	1.25	2.5	3.75	5.0	10	30
Was:	---	---	---	8 pr	20 pr	---	8 pr	---	---
Now:	24 pr	12 pr	---	52 pr	26 pr	11 pr	11 pr	---	---

e. 10.7-11.7 GHz band (was common carrier only)

bandwidth (MHz)	0.4	0.8	1.6	1.25	2.5	3.75	5.0	10	30	40
Was:	---	---	---	---	---	---	---	---	---	12 pr
Now:	---	---	---	56 pr	28 pr	14 pr	14 pr	50 pr	13 pr	12 pr

Although the old common carrier bands remain distinguished by the availability of wideband channels (20-MHz, 30-MHz, and 40-MHz bandwidths), it is likely that the fixed microwave bands will gradually become more homogeneous in patterns of use, being shared equally by private and common carrier users.

1.8 Release of 255 MHz of Federal Spectrum

Under Title VI of the Omnibus Budget Reconciliation Act of 1993 [4], Congress required the Federal Government to release at least 200 MHz of spectrum to the FCC, which would reallocate it for commercial purposes. Under Title III of the Balanced Budget Act of 1997 [5], Congress required the Federal Government to give up an additional 20 MHz of spectrum; these bands are designated by an "*" in the following table. These frequency bands and their corresponding release dates and conditions have been identified by NTIA and accepted by the FCC [6].

Table 1.1. Frequency Bands Released by NTIA

FREQUENCY BAND	RELEASE DATE	PREVIOUS USE
139-140.5 MHz*	January 2008	Fixed, mobile
141.5-143 MHz*	January 2008	Fixed, mobile
216-220 MHz*	January 2002	Miscellaneous
1385-1390 MHz*	Completed	Fixed, radar, mobile
1390-1400 MHz	Completed	Fixed, radar, mobile
1427-1432 MHz	Completed	Fixed, mobile
1432-1435 MHz*	Completed	Fixed, mobile
1670-1675 MHz	Completed	Radiosondes, met sat
1710-1755 MHz	January 2004	Fixed, mobile
2300-2310 MHz	Completed	Radar, mobile
2385-2390 MHz*	January 2005	Radar, mobile, tm
2390-2400 MHz	Completed	Radar, mobile
2400-2402 MHz	Completed	ISM, radar, mobile
2402-2417 MHz	Completed	ISM, radar, mobile
2417-2450 MHz	Completed	ISM, radar, mobile
3650-3700 MHz	Completed	Radar
4635-4660 MHz[4]	Completed	Fixed, mobile
4660-4685 MHz[2]	Completed	Fixed, mobile

[4]The 4940-4990 MHz band has been exchanged by NTIA for the 4635-4660 MHz and 4660-4685 MHz bands under the substitution authority of the President to facilitate the deployment of a new Navy system.

It is significant that the largest segments reallocated include bands used by the Government primarily for fixed services, especially the 1710-1755 MHz and the 4940-4990 MHz bands. These recent reallocations are mentioned in the respective sections of the report.

1.9 Allocation of 2 GHz Spectrum for Mobile Satellite Service (MSS)

Although Section 1.7 discussed the creation of the PCS bands from the 1850-1990 MHz fixed service band, the Emerging Technologies allocation also identified the 2110-2150 MHz and 2160-2200 MHz bands with common carrier (CC) and private (PRI) allocations for future reallocation to new services, including mobile satellite services (MSS). The matter has not yet been fully decided, but the proposed changes as of November 1998 [7] are summarized in Figure 1.9-1.

These changes include the following major features. Two paired MSS bands were created–an uplink band at 1990-2025 MHz and a downlink band at 2165-2200 MHz. The broadcast auxiliary service (BAS) band originally at 1990-2110 MHz was reduced and moved to 2025-2110 MHz. A new general-purpose fixed and mobile band was created at 2110-2150 MHz, with the intention of auctioning the band and allowing the auction winners to decide the details of its use. The MDS frequencies at 2150-2160 MHz or 2150-2162 MHz remain unchanged.

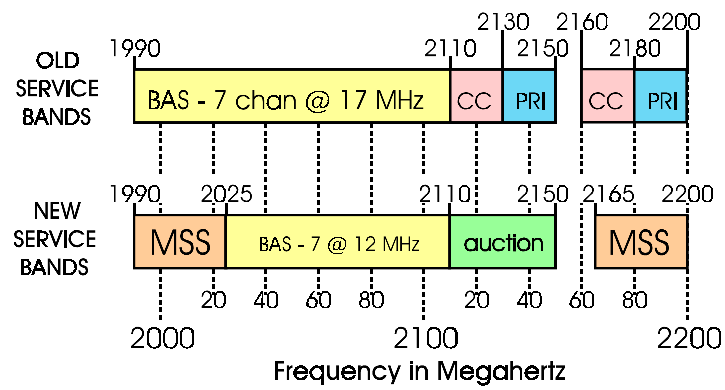

Figure 1.9-1. Allocation changes at 1990-2200 MHz

As with the earlier Emerging Technologies allocations, it is intended that licenses in the general-purpose fixed and mobile band will be auctioned. The winners of these licenses and the MSS licenses will have the option of designing new systems that do not interfere with the existing fixed users, or paying the costs of moving the existing users to new frequency bands. Many of the details are not yet decided, but some of the problems include:

1. Almost all existing users will need to be moved before any service can begin. Because of the global nature of MSS systems, presumably many existing users will need to be moved before service can start. This contrasts with the earlier Emerging Technologies moves, where the incumbent users could be moved one geographical area at a time by the new licensee who would pay to move those particular incumbents in that particular geographical area. Moreover, previous PCS licenses could concentrate on moving users out of a few urban areas, gaining large numbers of potential customers with relatively small displacements of existing users. The MSS customers are (almost by definition) spread throughout the countryside, i.e., wherever there is insufficient traffic demand to build a cellular/PCS system. Thus, MSS requires larger areas to be cleared of incumbent users before new services can be offered to a substantial number of customers.

2. The existing 120 MHz-wide BAS band will be squeezed into a new 85 MHz-wide BAS band. This move depends on reducing the BAS channelization bandwidth from about 17 MHz to only 12 MHz, which may require all of the old 17-MHz analog equipment used for TV electronic news gathering (ENG) to be replaced by new 12-MHz equipment using digital compression. The lack of compatibility between the old

and new equipment and channelizations may make it difficult to replace old equipment piecemeal, possibly requiring a single coordinated switchover date.

2. SUMMARY OF CURRENT BAND-BY-BAND USE

This section summarizes the usage in about 30 frequency bands having a primary allocation to the Government or non-Government fixed services. The bands are arranged in ascending frequency order, and each section follows the same general pattern of presentation. Information on the allocations for each band and a description of the significant uses for the band are presented. Numerical information is presented for each band, including the geographical distribution of assignments and a recent history of the number of licenses. The technological, regulatory, and market factors that affect the use of the bands are described. Finally, a prediction is made for the future growth (or decrease) in the number of assignments in the band in the next 5 years.

The emphasis in this report is on fixed services, not on individual frequency bands. Therefore, the following band summaries put more emphasis on a description of the fixed services in a given band and less emphasis on cataloging all of the non-fixed services which may share a particular frequency band. This usually causes no problems in understanding the fixed service use in non-Government bands, where each band is used according to a channelization plan and contains systems that are highly homogeneous in their characteristics. There are some non-Government bands (e.g., the 4-GHz common carrier band) where extensive sharing with dissimilar systems (e.g., satellite downlinks) limits the use of fixed systems; we have specifically mentioned the non-fixed services in these cases.

The problem of sharing with non-fixed systems is often more complicated in the Government bands. Government bands are often less homogeneous and follow channelization schemes to a less rigorous degree. The 1710-1850 MHz band, for example, contains not only a wide variety of terrestrial point-to-point links, but also mobile radio, aeronautical mobile links (including wideband video and telemetry), satellite links, and some classified systems. In the 1710-1850 band, the additional services represent a minority of the total number of assignments, but they substantially constrain use of the band for fixed systems. Because of the wide variation of system characteristics and rapid changes in system deployment, the constraints may not be easy to describe, except on an individual basis for each type of system. That level of detail is beyond what was intended for this document.

2.1 Methodology and Approach

The number of assignments/licenses in each band was obtained from one of three sources, depending on the frequency band. Note that NTIA uses the term "assignment" to mean the same as an FCC "license;" we will use the terms interchangeably in this report. The Government Master File (GMF) from NTIA was processed to obtain data on the Federal frequency bands. Data files from Comsearch (Reston, VA) were used to describe use in most of the non-Federal frequency bands. For some shared bands (i.e., shared between Federal and non-Federal users), we used GMF data for Federal use and Comsearch data for non-Federal use. For MDS and MMDS bands, we used license data that we had obtained earlier (December 1993) from Dataworld, Inc. (Bethesda, MD).

Data for each band includes four basic sets of numerical information:

1. the current geographical distribution of fixed assignments (July or September 1998),
2. a statistical distribution of fixed assignment geographical densities (July or September 1998),
3. a statistical distribution of channelization bandwidths (July or September 1998), and
4. a historical trend summary of the total number of assignments at the end of the 11 years.

For most services, only the transmitters were counted. In some bands with TV receive-only (TVRO) terminals, we also present information on receivers, because their presence greatly affects the use of the bands. A typical point-to-point two-way microwave link will count as two items, one count for the transmitter on each end. If a particular link bandwidth needs to be expanded–for example–from 2.5 MHz to 5.0 MHz, this process might or might not result in a larger number of licenses counted. If the expansion were accomplished by adding a license for an additional 2.5-MHz channel, this would increase the count. If the 2.5-MHz channel were changed to a 5-MHz channel, the license count would not change on a long term basis. During the transition from 2.5 MHz to 5 MHz, however, both (old and new) licenses might be counted; the old 2.5-MHz channel license would be deleted after the 5-MHz channel was installed.

2.1.1 Geographical and Statistical Data

The geographical and the statistical presentations were obtained from the most recent data sets that were available. The information on current Government band assignments was developed from the September 1998 GMF, usually selecting only fixed assignments. For this study, Government station classes of FX, FXD, FXE, and FXH were considered fixed services. Although many Government bands also contain significant numbers of non-fixed assignments, this study focuses on the fixed services. Current non-Government license data was developed from the July 31, 1998 Comsearch files. For MDS and MMDS bands, we used license data that was obtained earlier in December 1993 from Dataworld, Inc. (Bethesda, MD). When possible and significant, we divided the assignments into separate user categories, since this may make trend information easier to understand. Geographical and statistical data are not necessarily commensurate and comparable between different bands and services. The nature of some services makes them difficult to compare with other services. Nevertheless, all bands were treated in as similar a manner as possible. The Government assignment count usually includes classified assignments, but generally does not show the number of pieces of equipment each assignment represents. For example, the entire inventory of the (fictitious) ABC-123 transportable microwave terminals will often be represented by a few assignments (e.g., one assignment for each facility using that equipment). However, any ABC-123 terminal permanently installed at a particular site would typically have an individual assignment for each permanently installed transmitter. Many of the details of exactly how assignments were treated were not recoverable from the pre-1991 archival file summaries that we used to get the Government historical information. Similarly, we did not ask for Comsearch data to break out cellular users before 1994.

2.1.2 Geographical Maps

Each frequency band is described with a map showing the geographical distributions of fixed assignments in the United States. An example of a geographical map is shown in Figure 2.1-1. The geographical area of the United States was covered by a grid with 1-degree resolution in latitude and longitude, creating about a thousand 1-degree by 1-degree blocks. Circles of various sizes were placed at the center of each of these blocks; the size of the circle indicates the total number of transmitters in that block. The absence of any circle shows that no transmitters were present in that block. These maps show usage patterns that help to understand how the bands are used on a geographical basis–e.g., whether the band is used mainly in rural or urban areas. This information might be useful in possibly suggesting services that might be particularly amenable to sharing on a geographic basis. Note that these maps show only the fixed services; the absence of fixed assignments does not imply an absence of other types of assignments.

This geographical mapping is intended to show relative usage in a single band between various geographical areas in the United States, rather than the difference in crowding between the various frequency bands. Therefore, the values representing the number of transmitters in each block have been scaled according to the number of transmitters in the band. This means that the map of a lightly used band might have the same appearance as the map of a heavily used band. The scales on these maps should be checked before using these maps to compare the usage between several frequency bands. The scales used in these maps match the scales used in the 1993 staff study (chosen as described above), which was done to facilitate a comparison of the maps to identify areas of change. Therefore, in many cases a “blacker” map may indicate growth and a “lighter” map may indicate shrinkage, rather than being crowded or sparse.

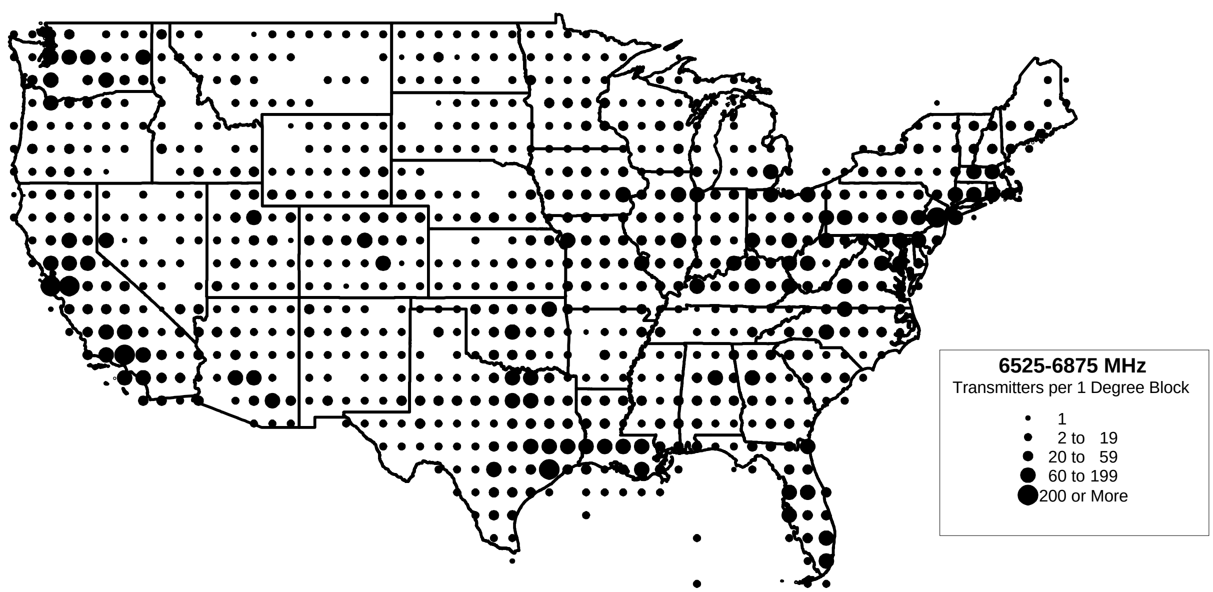

Figure 2.1-1. Example of a geographical distribution map.

Finally, note that the maps show only the number of licenses within a block, without reference to the bandwidths associated with these transmitters. It is possible that some geographical areas using fewer transmitters with wider bandwidths may actually be more crowded (from a spectrum usage standpoint) than an area using a larger number of narrowband channels. (See discussions on bandwidth in Section 2.1.5.)

2.1.3 Statistical Tables

The statistical tables for each band contain a summary of some of the more important statistical information for the band, illustrated by the example in Table 2.1.

1. Total US (fixed) assignments. This is the total number of U.S. fixed assignments/licenses in that band, as enumerated in the July 1998 Comsearch database or the September 1998 GMF database. The first five rows in the table all were derived from these databases. In the case of the Federal bands, the data is for fixed assignments only.

2. Maximum assignment density. This is the highest number of assignments found in any 1-degree by 1-degree block in the United States. This number was obtained from the data used to plot the geographical map for each band. It is equal to the largest density value in the license density statistics graph (Section 2.1.4).

Table 2.1. Example of Table of Statistics for the 944-952 MHz Band

total US assignments	6174
maximum assignment density	64
effective number of channels	23.4
average U.S. channel reuse	264
peak reuse/1-degree block	2.7
annual growth (last 4 yr)	26%
est. annual growth (next 5 yr)	20%

3. Effective number of channels. This number represents the effective number of channels in the band, based on the channel bandwidth statistics from user licenses. It is used only to calculate the channel re-use numbers. For a band that is divided into a single set of equal bandwidth channels, this number is simply the total number of channels in the band. When the band can be divided into channels of different bandwidths, or when channels are customarily assigned by combining a number of narrowband channels to obtain the required bandwidth for a particular system, the effective number of channels is not so easy to determine. For these cases, this number is computed by dividing the total bandwidth in the band by the average channelization bandwidth (see Section 2.1.5 for details on average channelization bandwidth). For most Government bands, the effective number of channels was found by dividing the total bandwidth by the average user bandwidth.

Note that many of the private and common carrier bands have been rechannelized since the 1993 staff study, adding narrower channelizations suitable for relatively narrowband SCADA, cellular, and PCS applications (matching the application bandwidths needed by many users migrating from the 2-GHz Emerging Technology bands).

4. Average U.S. channel re-use. This field shows, on the average, how many times a typical channel was re-used over the entire United States during July or September 1998. It is obtained by dividing the total number of U.S. licenses (item 1) by the effective number of channels in a band (item 3, described in the preceding paragraphs). This factor is useful for comparing "crowding" between bands, though many other operational and technical factors may modify this simple comparison.

5. Peak re-use/1-degree block. This field shows the number of times that an average channel was re-used within the single 1-degree geographical block with the highest number of assignments. This shows how often a given channel was re-used within the most heavily crowded conditions. It was obtained by dividing the peak number of licenses in a 1-degree block (item 2) by the effective number of channels (item 3).

This data may be misleading for frequency bands that have multiple channel bandwidths. Specifically, the calculation of this number assumes that the distribution of channel bandwidths in the "peak re-use" block is the same as it is in the United States as a whole. Moreover, the most-crowded block is selected by considering only the number of licenses, without regard for the bandwidths associated with those licenses.

Nevertheless, peak re-use data attempts to describe the actual areas of the worst spectrum crowding in the U.S. on a band-by-band basis. This number is useful for comparing worst-case crowding between bands, though many other operational and technical factors may modify this simple comparison. This data might also be used to infer that the practical upper limit for band usage must be at least as large as this number, as well as to suggest which frequency bands may be near that limit.

6. Annual growth rate (last 5 years). This field was calculated from the 11-year chart of annual licence data (Figure 2.1-4) to give the compounded annual growth rate which would have been needed to change the number of 1992 licenses to the number of licenses in 1997. Note that this historical data comes from data sets that were current at the end of each nominal calendar year, which is a different set of data than was used for the immediately preceding five items. (See further details in Section 2.1.7.) This data and the underlying causes are described more fully in the historical trends paragraph. In some cases, a different starting date was selected to more accurately describe the growth mechanisms that are believed to be currently active and expected to affect future growth.

7. Estimated annual growth (next 5 years). This is the annual percentage change for (compounded) growth that would be required to convert 1997 license numbers to the expected license numbers five years from now. It is described more fully in Section 2.1.9.

2.1.4 License Density Statistics Graph

The license density statistics graph (Figure 2.1-2) is based on the same information found in the geographical map, but the graph organizes this data as a cumulative statistical distribution. This distribution shows what percentage of the 1-degree blocks contains a total number of licenses equal to or greater than the density shown on the ordinate. The example graph uses data from the 5925-6425 MHz band (not shown in Section 2.20).

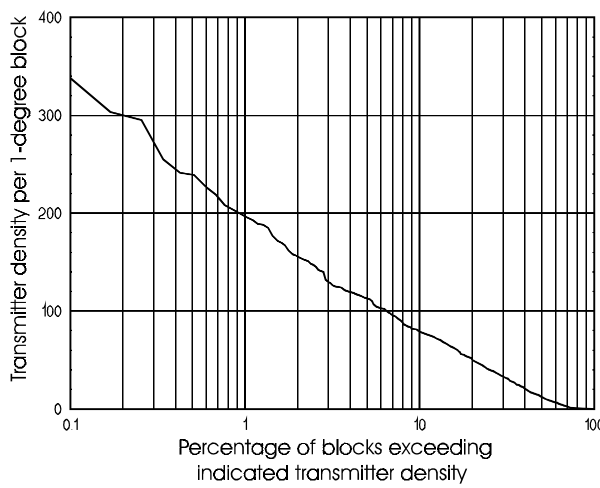

Figure 2.1-2. Example of a license density statistics graph (5925-6425 MHz band).

The graph shows the degree to which licenses are uniformly distributed on a geographical basis. If all 1-degree blocks had the same density of transmitters, the graph would approximate a horizontal line at the level of the density. The example graph shows that the highest density of transmitters was about 340 assignments in a 1-degree block (which agrees with the "peak assignment/1-degree block" entry of "338" in Table 2.20-1), that about 1% of the blocks have at least 200 assignments or licenses, and that 10% of the blocks have at least 80 licenses.

For the purposes of this calculation, it was determined that the United States included 951 1-degree by 1-degree blocks. Therefore, the highest number of licenses in a single 1-degree block is plotted at the 0.1 percent position (the left margin of the graph). The count of 951 blocks includes some non-land coastal areas immediately adjacent to the United States (especially in the Gulf of Mexico, where substantial numbers of transmitters provide service to petroleum production facilities). It also counts any 1-degree block that touches the U.S. border, if that block also contains at least one U.S.-licensed radio in any frequency band included in the study.

For most frequency bands, the license density statistics graph or the user bandwidth chart (but not both) was included in the 2-page summary section. The selection was usually based on what information was available or which graph provided the most useful information.

2.1.5. User Bandwidth Graph

As part of the relocation of fixed systems from the 2 GHz bands (which contained large numbers of narrow bandwidth channels), the FCC added narrowband channelizations to most of the migration destination bands. As a consequence, many fixed bands now have channels that vary over a wide range of bandwidths–e.g., a 75:1 range in the 6 GHz band. Therefore, when analyzing potential band-crowding conditions, it is now important to consider the bandwidth of licensed channels as well as the total number of licenses. For example, in the case of the 6 GHz band, as much as a 75-times increase in the number of licenses might not represent any actual increase in spectrum usage, if all of the new population of licenses were for the narrowest-bandwidth channelizations. Furthermore, a knowledge of channel bandwidths provides important information about the ways that the channels are being used by various industries, and this information may be useful in forecasting trends about those industries.

Figure 2.1-3 shows a typical bandwidth distribution graph. The number of channels licensed for various bandwidths is shown for several groups of users. In most cases, the licensed bandwidth was obtained by examining the channel group designator for each license (since each channel group has a specific channel bandwidth). In a few cases, it was necessary to infer the bandwidth from the emission designator information. Finally, in a small number of cases, it was necessary to guess at the bandwidth by examining the application.

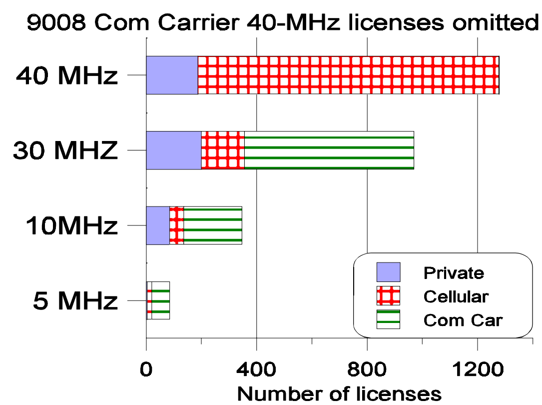

Figure 2.1-3. Example of a typical user bandwidth graph (10.7-11.7 GHz band).

This procedure often resulted in a large number of bandwidths, including some that did not correspond to the nominal channelization bandwidths available in a particular band. These bandwidths were combined into convenient groups and plotted on the bar graph according to the following rule: Each bar is labeled with the highest bandwidth included in the count, and it contains all bandwidths down to the limit of the next lower bar. In the 10.7-11.7 GHz band shown in the example graph, there are channelizations that provide for bandwidths ranging between 1.25 MHz and 40 MHz. However, the graph does not actually show each of the channelization bandwidths for each of the user groups. Instead, the graph shows only selected combinations of user groups and bandwidths. This selection was necessary because numbers in some categories were either much larger or much smaller than others, as well as the presence of various intermediate bandwidths.

The following rules were used in placing licenses into various bandwidth categories. The bar with the lowest bandwidth contains all licenses with bandwidths less than or equal to the labeled bandwidth. Therefore, in this chart, the “5 MHz” bar includes all licenses with bandwidths of 5 MHz or less, including 1.25-MHz, 2.5-MHz, 3.75-MHz, and 5-MHz channelizations, as well as any miscellaneous bandwidths within this range of bandwidths. The remainder of the bars contain licenses with bandwidths less than or equal to the labeled bandwidth, but greater than the labeled bandwidth for the next lower bar. Therefore, the “10 MHz” bar contains the count for all licenses with bandwidths greater than 5 MHz, but less than or equal to 10 MHz. Finally, the reader should note the statement immediately above the graph that says“9008 Com Carrier 40-MHz licenses omitted.” In this band, 40-MHz bandwidth common carriers account for the great majority of licenses in the band, but including this category within the graph would require changing the scale on the graph to the extent that the other categories would be almost invisible. Therefore, the 9008 common carrier licenses with 40-MHz bandwidths were omitted from the graph, but included in the statement above the graph.

The data from the bandwidth chart were also used to calculate the average bandwidth for the band. The averages were calculated by summing the channel bandwidths of all licenses and dividing by the number of licenses. As described earlier, most of the bandwidths used in this calculation are the nominal channel bandwidths, instead of the bandwidth of the actual emission in the channel. Since a user will typically need to select a channelization bandwidth that is at least as large as the intended emission, channel bandwidths may be somewhat larger than the actual emission bandwidths. The degree to which these bandwidths may be inflated by requesting bandwidths sized for larger anticipated future requirements is not known.

In the Federal GMF records, the most easily accessible bandwidth is contained in the emission designator. This bandwidth is equal to the actual emission bandwidth, instead of the nominal channelization bandwidth. Therefore, the values of listed Federal bandwidths are considerably smaller than bandwidths from non-Federal bands. In most cases, the average Federal bandwidths were adjusted upward to match comparable channelization bandwidths that would have been calculated for non-Federal licenses. For example, in the 406-420 MHz Federal band, most radios are assigned in 25-kHz channels, but the emission designator is “16F3"—which denotes a 16 kHz emission bandwidth. For purposes of this paper, 16F3 was counted as 25 kHz. Partly because of these difficulties, no bandwidth graphs were included for Federal bands.

The average bandwidth for all users in a band is used to calculate the effective average number of channels in a band (see Section 2.1.3, describing the Statistics table). Specifically, the average number of channels is calculated by dividing the total bandwidth in the entire band by the average bandwidth of users. This often gives an average number of channels that is not necessarily an integer.

The average number of channels is used to calculate the average number of times that a given part of the spectrum in a band is reused within the United States (average US channel reuse), and the number of times that a given frequency is reused within the most crowded 1-degree x 1-degree geographical area (peak reuse 1-degree block). The “US-average” data is accurate; the “peak reuse” data may not be accurate. The problem with the “peak reuse” data is that the calculations assume that the distribution of channel bandwidths is the same for the most crowded area as it is for the whole US average. In fact, the most-crowded area was selected by merely counting the number of licenses within the area, without regard for the channel bandwidths associated with those licenses. It is theoretically possible that the area with the most licenses is composed mostly of licenses for narrower channels, and that it is less crowded than an area having fewer total licenses (but more licenses for wider bandwidth channels). However, although the most-crowded-area calculations may be incorrect (strictly speaking), they are still believed to provide useful insights, and the strictly correct calculations would have required much more detailed data and more elaborate calculations.

Finally, it should be noted that the bandwidth distribution graph was not included for several bands. Bandwidth graphs were omitted when bandwidth data was unavailable or when the bandwidth data was uninteresting (e.g., when there was only one channelization bandwidth).

2.1.6 Typical Users

This information describes the current set of typical applications found in a band, along with other information that may help the reader understand how a band is being used. In some cases, we have given independent assignment counts for different types of users. This information came from various sources—often from different sources than were used for the geographical and statistical data or the trend data. We note that totals often do not match exactly between the sources, but we believe that this information is still useful to give an approximate indication of the numbers of different users. Most of the information on the number of agency assignments in Government and shared bands came from the September 1998 GMF. Average bandwidth data reported in this section was computed from 1998 data.

2.1.7 Recent Trends in Number of Assignments

Figure 2.1-4 shows historical license trend information for the 1987-1997 period for the 406.1-420 MHz band. The bars represent end-of-year data, either from the last months of the respective year or from early months of the following year, depending on what was available. The Comsearch data was taken from files archived on December 31 of each year. The GMF data before 1992 was taken from the initial part (usually January) of the following year. Therefore, a bar that is labeled "1990" would contain December 1990 numbers if it is describing a non-Federal band (Comsearch data), but January 1991 data if it is describing a Federal band (GMF data). Beginning in 1992, we had more ability to select GMF data. The Federal data from 1992-1997 were derived from December 1992-1997 GMF databases, respectively.

In many of these graphs, the users are divided into particular groups so that different trends can be distinguished and attached to individual user groups. The example graph contains two sets of users: “mobile, etc.” and “fixed only”. The shaded “mobile, etc.” bars contain either a mixture of user types (1990 and earlier, when no division between user groups had been made) or mobile and other non-fixed users (after 1991). The striped “fixed only” bars contain only fixed users, wherever these bars exist in the graph. Similar divisions will be made on other graphs.

It should be noted that the GMF records allow multiple station classes to be associated with a single assignment. An assignment was counted as “fixed” if any of its associated station classes were in the fixed category.

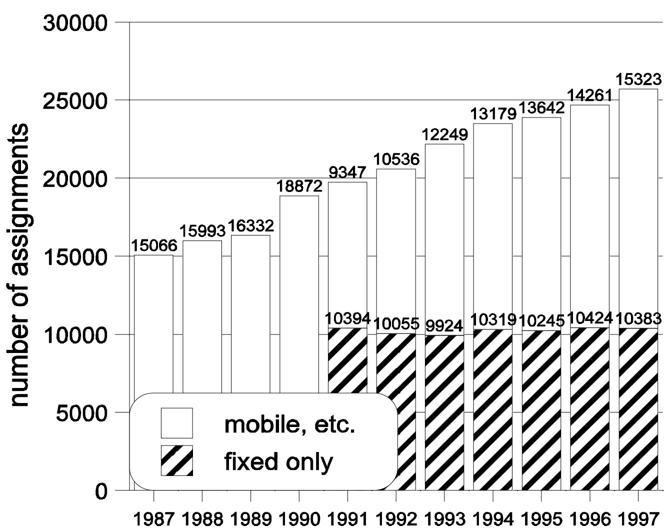

Figure 2.1-4. Example graph for number of assignments (406.1-420 MHz band).

The pre-1992 archived Government data could not easily be sorted for the assigned service; it was necessary to use the total number of assignments in a band, combining all types of users. The average growth rate (last 5 years) was obtained from the 1992 and 1997 data. The calculated growth rate is the compounded annual rate (constant) that predicts the net growth from 1992 to 1997. In some cases, where obvious changes of slope had occurred more recently than five years ago, we adjusted the calculations to use a different starting year and corresponding term of growth.

The historical data is useful to show which bands are becoming more or less crowded. This information is based completely on frequency assignment counts, however, and it does not necessarily show whether the indicated assignments are actually being used or being implemented with wider or narrower bandwidths. In many bands, there is no mechanism to ensure that users turn in their frequency assignments when they are finished using them. Particularly in a frequency band whose use has been decreasing, the assignment database information may lag behind the actual usage. The database manager may learn of the departure of the equipment only when the user fails to renew an assignment when it expires several years later. In addition, we understand that some point-to-point common carriers have been instructed to terminate licenses at a given site only when the last transmitter in a band ceases operation. Similarly, in bands where there is a lot of activity associated with relocation and re-use of transmitters, apparent growth may be caused by the requirement to obtain a new license each time a transmitter is relocated or when its ownership is changed. The corresponding mechanism for deleting the old license is not necessarily as certain or swift, which could cause license data to become inflated with obsolete licenses. The degree to which this effect causes a significant distortion of usage trends is unclear at this time.

2.1.8 Comments

The "Comments" section contains any additional information that may be helpful in understanding the current or future use in a band, including general market trends, technology factors, or regulatory actions that are expected to significantly affect future use of the band.

2.1.9 Estimated Future Growth Rate

This section indicates the predicted annual percentage growth, averaged over the next 5 years. The growth rate derived in this section is also included in the table of statistics for the band, described as part of Table 2.1. In some bands, we expect that the growth rate will change substantially over the next 5 years, so that the present growth rate will be considerably different from the predicted average growth rate. The growth rate was calculated by estimating the number of assignments at the end of the year 2002 and calculating the average annually compounded growth rate needed to achieve that number. If the number of assignments is expected to decrease, the growth rate is expressed as a negative number. For example, a -5% growth rate would mean that each successive annual assignment count contained 95% of the assignments counted in the previous year. A narrative description of the factors that were included in that prediction are found in each band description in the paragraph on "estimated future growth rate."

It should be noted that the estimated growth rate for each band is based on a large number of technological, regulatory, and economic factors, each of which may be subject to uncertainty and possible errors. The regulatory environment is a particularly important factor, and it is one that may be changing rapidly. It is particularly difficult to estimate future growth in bands where the allocations are scheduled to change soon, but where no detailed rules have been established yet for the proposed new services. In certain cases there may be a surplus of spectrum for new services, and actual use of the band may be pushed mainly by regulatory requirements for rapid build-out.

Pages 20-77 omitted from this file.

Pages 20-77 omitted from this file.

2.31 Usage in the 24.2-24.45 and 25.05-25.25 GHz Bands
Public Service

Typical users. The “24 GHz band” (24.25-24.45 GHz and 25.05-25.25 GHz) was reallocated in March 1997 for use by digital electronic message service (DEMS). The band is allocated as five pairs of 40-MHz channels, with respective paired channels separated by 800 MHz. These channels will be allocated by Economic Areas (EA’s). The licensee will be expected to divide the frequency bands and geographical areas into smaller pieces, as required for the technical details of the system to be implemented. In addition, unlimited aggregation or disaggregation of frequencies and geographical areas will be permitted between various licensees.

Comments. Wireless local loop (WLL) services in this band began as digital electronic message services (DEMS) moved from the 18 GHz band. Although DEMS had been barely used for many years in the 18 GHz band, recently it had been identified as a practical means of providing WLL services and considerable expansion of DEMS was planned. A closer inspection of DEMS in the 18 GHz band, however, exposed the possibility of interference to some existing and planned 18 GHz satellite systems. The problem was solved by moving DEMS from 18 GHz to a new (previously Federal) band near 24 GHz.

Teligent Corp has most of the licenses in this band and has announced that it will provide WLL services in 30 major metropolitan areas by the end of 1999. This service will be based on a point-to-point or point-to-multipoint architecture that will provide fixed wireless access to commercial businesses, typically with T1 or multiple T1 services.

Estimate of future growth. We believe that growth in this band will be rapid over the next 5 years, as Teligent is aggressively developing systems in many major US cities. However, this service will be competing head-on with other new HDFS services at 28 GHz (LMDS) and 39 GHz (wireless fiber); the eventual outcome of this competition cannot be predicted with any certainty.

2.32 Usage in the 25.525-27.5 GHz Band
Government Service

Typical users. This Federal Government band is virtually unused by the fixed services, having a total of 20 developmental and experimental fixed assignments belonging to the Army and Justice. However, NASA is planning to build the next generation of its TDRSS data relay satellites in this band.

Comments. No commercial systems have been installed in the band.

Estimate of future growth. This band will probably grow substantially in the future. However, it is not clear which services will be allocated to this band by the time that growth occurs.

2.33 Usage in the 27.5-31.3 GHz Band
Public Service (LMDS)

Typical users. This band was auctioned in March 1998 for about $580 million for the purpose of providing local multipoint distribution service (LMDS). Although no large scale deployment has begun yet, CellularVision has been using 15 transmitters in the New York City area to provide Internet access and TV to 18,000 customers.

Comments. The auction divided the band into Block A and Block B subbands in 493 Basic Trading Areas (BTA's) across the United States. The Block A licenses provide 1150 MHz of spectrum (27.5-28.35 GHz, 29.1-29.25 GHz and 31.075-31.225 GHz). The Block B licenses provide 150 MHz of spectrum (31.0-31.075 GHz and 31.225-31.3 GHz). Earlier planning for this band had suggested point-to-multipoint one-way distribution of analog TV using multiple short-range (up to 3 miles in range) line-of-sight transmitters, giving the service the name "cellular cable." A small (6" diameter) highly-directional customer antenna would select the best-positioned transmitting site and overcome some of the path loss. More recent planning suggests that the service will be two-way digital, providing a full range of telecommunications services–including wideband Internet access, telephone, compressed digital TV, etc. The relatively short range and use of directional antennas would permit a large degree of frequency reuse and higher bandwidths to each user.

Estimate of future growth. The use of this band is expected to expand rapidly, especially in the near future, as auction winners build out infrastructure in most major metropolitan areas in the next few years. However, because this service will be competing head-on with other new HDFS services at 24 GHz (WLL) and 39 GHz (wireless fiber), as well as broadband digital cable services and LEC ADSL, the outcome of this competition cannot be predicted with any certainty.

2.34 Usage in the 38.6-40.0 GHz Band Public and Private Services

39 GHz band. The 39 GHz band (38.6-40.0 GHz) is proposed to be allocated for a wide variety of services, including terrestrial point-to-point, point-to-multipoint, and (possibly) mobile services. The allocation for this band is currently established under Memorandum Opinion and Order FCC 99-179, adopted in July 1999. The band is available for use by common carrier and private users, and plans are being made to auction the band by dividing the United States into 172 Economic Areas (EAs) and 3 EA-like areas outside the continental U.S. Early uses of the band are expected to include interconnection of cellular and PCS sites, bypassing incumbent LECs and connecting business customers directly to competitive LEC switches, and wireless local loop service to individual consumers.

The 39 GHz band is channelized in 14 pairs of 50-MHz blocks, with corresponding paired blocks separated by 700 MHz. Permission was granted to early licensees to use a given pair of 50-MHz blocks over a self-declared rectangular geographical area, though licenses awarded by auctions will be divided geographically into EAs and unpaired 50-MHz bands. It is expected that a user will subdivide the 50-MHz bands into smaller channels and areas, suitable for a cellular-like frequency reuse architecture. Users will be responsible for their own internal frequency coordination, as well as selection of technologies, bandwidths, modulation, antenna performance, etc. Fixed point-to-point and point-to-multipoint operation is permitted. Coordination between users will be required for sites within 16 km of geographical boundaries on co-channel and adjacent channel frequencies, though no specific power flux density limits have been set for signal leakage across boundaries. Existing blocks can be subdivided or aggregated on a geographical or frequency basis and sublicensed to other users. Licenses for three pairs of frequency blocks will be auctioned at one time, resulting in four independent auctions, with the first auction planned near the end of 1999. Note that the 39.5-40.0 GHz subband is also allocated for Federal satellite operations.

Winstar Corporation is a major user in this band, providing fixed microwave links to bypass the incumbent LECs and to provide wideband links to urban locations where optical fiber is not yet available (a service that Winstar calls “wireless fiber”). A typical Winstar deployment strategy is to place fiber- or microwave-connected switches in several tall buildings located several miles apart. From these hub buildings, directional 39-GHz point-to-point links or segmented point-to-multipoint links are set up to many buildings within a several-mile radius. It is claimed that this strategy can provide wideband connections to many business customers more rapidly and more economically than wireline or fiber alternatives. The 39-GHz links are limited to relatively short, line-of-sight applications because of precipitation-related path loss. On the other hand, the high frequency band permits the use of many small, high-performance antennas giving enhanced frequency reuse.

2.35 Other Frequency Bands of Interest

This section mentions additional selected bands with existing or proposed fixed allocations, or allocations which would permit their use to provide services similar to fixed services. These selected bands do not include all of the additional bands with fixed or “similar-to-fixed” allocations.

2.1 GHz band. The 2110-2150 MHz band is being created from half of the existing paired common carrier and private operational fixed service bands. The licenses in this band will be auctioned, and the new licensees will be required to reimburse the incumbent fixed service users for the expense of moving to a new band.

2.3 GHz band (WCS). The wireless communication service (WCS) bands are 2305-2320 MHz and 2345-2360 MHz. The intervening 2320-2345 MHz band is allocated for the digital audio radio service (DARS). The WCS band was auctioned in April 1997 for about $15 million. It was licensed as paired 5-MHz subbands over 52 major economic areas (MEAs) or 12 regional economic areas (REAs). The WCS bands are allocated for a broad range of fixed and mobile wireless applications under Part 27 rules. At present, there has been little implementation of systems in this band, though several applications have been proposed. Some licensees have proposed using the band to extend the DARS service. Others have proposed fixed point-to-point services, WLL, or using the band as the reverse channel for an expanded two-way digital MMDS system.

3.65-3.7 GHz band. This band was released by the Federal government under the requirements of the 1993 Omnibus Budget Reconciliation Act. It was allocated to non-government Fixed services by FCC 98-337, an NPRM released December 1998. The NPRM suggests that this band would be especially suitable for WLL and fixed wireless access (FWA). Existing Military radars are grandfathered at three U.S. sites and high-power airborne radars remain in adjacent bands.. Frequencies in 3.4-3.7 GHz range are expected to be used for WLL in many countries (including Mexico).

4.9 GHz band (GWCS). The general wireless communication service (GWCS) bands include 50 MHz of Federal spectrum in the 4400-4990 MHz band, to be licensed via auction by the FCC. The 50 MHz of spectrum originally included the 4635-4660 MHz and 4660-4685 MHz bands. Although these bands were scheduled to be auctioned, the FCC postponed the auction because of an apparent lack of interested bidders. Recently, NTIA requested that the previous bands near 4.6 GHz be exchanged for the 4940-4990 MHz band. Licenses in this new band will presumably be auctioned in the near future for a wide range of wireless services, though no details are available yet.

5 GHz U-NII band. The unlicensed national information infrastructure (U-NII) band includes the 5.150-5.350 GHz and 5.725-5.825 GHz frequency bands. A wide range of unlicensed applications is permitted, including point-to-point and point-to-multipoint uses. Permissible transmitter power is proportional to bandwidth (up to a 50-MHz maximum bandwidth), with the expectation that this service will be used only for wideband data transmission, such as wireless LANs. Note that the 5.725-5.825 GHz band overlaps the 5.8 GHz ISM band, however, and narrowband devices could use this spectrum under the unlicensed Part 15/ISM rules.

37 GHz, 42 GHz, and 43 GHz bands. The 37-38.6 GHz band has shared Federal and non-Federal primary allocations for fixed and mobile services. The FCC has allocated the 41.5-42.5 GHz band for primary fixed and mobile services (suitable for general wireless services) The 42.5-43.5 GHz band has primary allocations for Federal fixed and mobile operations[14]. The 43 GHz band and 47 GHz band (see next paragraph) had initially been allocated to shared Federal and non-Federal operation, but were later reallocated to exclusive Federal and non-Federal services, respectively, to simplify management of those bands. Though details on all of these bands are not yet available, it is assumed that the ubiquitous wireless services that will use these bands will not necessarily be compatible with various satellite services. Therefore, frequency bands recently allocated in this general frequency range have been given primary allocations for terrestrial use or satellite use, but not both services in the same frequency band. These bands might also be used in conjunction with the 39 GHz band (Section 2.34).

47 GHz band. The FCC has established the 47.2-48.2 GHz band for exclusive non-Federal fixed point-to-multipoint services, including services delivered via stratospheric platforms–also called high altitude platform systems (HAPS) [15]. Though the rules have not been completed yet, it has been proposed that the rules will be optimized for stratospheric platforms, while permitting a wide range of other services. The band will include three 100-MHz paired blocks, with each 100-MHz block in the lower half of the band paired with a corresponding block 700 MHz higher in frequency. These paired blocks will be licensed by large geographical areas (12 regional economic area groupings–REAGs) to users via auctions (date not set yet). The users are expected to break the blocks apart (or aggregate them) as needed for particular applications.

Sky Station International, Inc. was the first to propose that this band be used for “stratospheric satellites.” These helium-filled high-altitude airships would permanently float 100,000 ft above major metropolitan areas, using large arrays of photovoltaic cells and active station-keeping to relay many types of data throughout a large metropolitan area. This concept combines many of the best telecommunication advantages of geostationary satellites and high terrestrial relay towers. However, there are substantial vehicle engineering challenges, and the feasibility of such platforms remains to be demonstrated. Other developers have proposed similar services using relay teams of long-duration high-flying aircraft or continuously-aloft solar-powered high-flying aircraft. The FCC has noted stratospheric satellites as the expected use of the 47 GHz band, but has not reserved any frequencies exclusively for this purpose.

59-64 GHz band. Signals in this band experience a 15-20 dB/km attenuation, caused by absorption by oxygen in the air. The FCC has established the 59-64 GHz band as a general-purpose unlicensed band under Part 15 rules, partly since the oxygen absorption will ensure that signals will rapidly decrease with distance, minimizing the possibility of interference. Users in this band must transmit a coded ID that will identify themselves, at least as often as once every second, as an aid to rapidly resolving any interference problems. In addition, the 59.00-59.05 GHz portion of the band is to be used in common by all users to assist in coordinating the real time use in the remainder of the band. Although there are no users in this band yet, the 5 GHz of total bandwidth and the ability to use directional antennas suggests that the band will be used for short-range, wide bandwidth, point-to-point links and omnidirectional WLAN applications.

Higher frequency bands. The recent allocations of the 47 GHz and 59-64 GHz bands are part of a larger FCC proposal to allow commercial use of a series of frequency bands extending up to 153 GHz (ET Docket No. 94-124 [16]). In general, the rules proposed for these bands are quite flexible, partly because the very high frequencies do not permit long-range propagation, reducing the potential for interference between users. Twelve frequency bands between 40 GHz and 153 GHz with a total of 18 GHz of spectrum are defined for a mix of licensed millimeter wave service (LMWS) and unlicensed Part 15 service.

Licensed bands		**Unlicensed bands (Part 15)**	
40.5-42.5 GHz	47.2-48.2 GHz	59-64 GHz	- - - -
71.0-71.5 GHz	84.0-84.5 GHz	71.5 -72.0 GHz	84.5-85.0 GHz
103.0-103.5 GHz	116.0-116.5 GHz	103.5-104.0 GHz	116.5-117.0 GHz
122.0-122.5 GHz	126.0-126.5 GHz	122.5-123.0 GHz	126.5-127.0 GHz
152.0-152.5 GHz	- - - -	152.5-153.0 GHz	- - - -

The Part 15 service would allow low power unlicensed operation for a wide range of services. The licensed operation is proposed to be licensed to a very general LMWS in larger frequency blocks over large geographical areas (Major Trading Areas—MTAs). The FCC will continue to define the specific rules for each of these bands over the next several years.

Few of these bands have any commercial use yet; most bands have no users. Presumably, the lack of current users is caused by lack of economical electronic semiconductor devices as well as special challenges of system design. However, these bands will not remain unused for long. Automotive manufacturers are working on short-range radar sensors in the 76-77 GHz band, and at least one cellular equipment supplier has mentioned the use of the 57-59 GHz band to link sites together.

3. COMPARISON OF PREDICTIONS WITH LICENSE DATA

The 1993 Staff Study on the fixed services predicted specific changes in the number of licenses in various frequency bands and fixed services. One purpose of the current study is to review the accuracy of the earlier predictions and to understand why deviations occurred. We are interested mainly in the major features of this comparison; minor deviations from predictions will be ignored. The following sections compare earlier 5-year license predictions with license data over the past 6 years.

The 1993 staff study made predictions based on the number of licenses issued (or assignments, in Federal bands) as a means of tracking the growth in the use of microwave fixed services. Although counting licenses may still be the best single indicator of activity, it surely seems to tell a diminishing part of the whole story. The increasing degree of flexibility in the use of individual frequency bands (multiple types of users, multiple services, multiple bandwidths) presents the danger of an “apples versus oranges” comparison, and the increasing number of transmitters that do not need to be individually licensed brings the probability of “blind spots” where large numbers of transmitters are missed.

3.1 Federal Government Service

The 1993 Staff Study estimated that the total average growth rate for the Federal bands would be 0.3% net increase per year for the next 5 years (Matheson [1], Table 4.2-3). Figure 3.1 shows the total number of assignments in the Federal bands, with the fixed assignments identified for the last 7 years. The breakdown between fixed and other services was not available in all bands, and some information was based on estimates.

The numbers of identifiable fixed assignments in the Federal bands were:

1991 - 28069
1992 - 28871
1993 - 29084
1994 - 29350
1995 - 30008
1996 - 30736
1997 - 30564

This gives an actual average annual growth for fixed services in the last six years of 1.4%. It should be noted that most of the growth between 1991 and 1992 was due to more than 800 assignments that were added for transportable terminals, as the result of a policy decision to individually license some of these systems. If this "paper growth" is subtracted out, the average annual growth in number of assignments was about 1%.

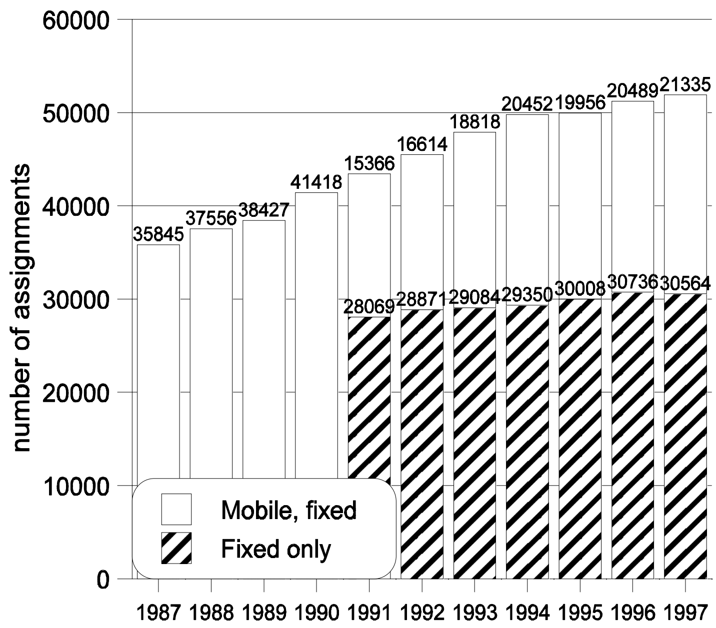

Figure 3.1. Total Federal assignments in fixed bands.

3.2 Private Operations Service

The total growth rate for the private operations services was estimated to be an increase of 3.2 percent a year (Matheson [1], Table 4.2-6). Figure 3.2 summarizes the number of licenses in the private services. The "Misc." category includes private license counts from the 2.4 GHz, 6 GHz, 10.5 GHz, 11 GHz, and 13 GHz bands. Most of these bands have small numbers of licenses, and many of them were only recently opened to private uses. The data in Figure 3.2 omits the 18-GHz private cable service, a service similar to CARS, that added more than 75,000 licenses over the last five years. Since the private cable service is quite different from traditional private services and quite similar to CARS, these licenses have been included with CARS (Section 3.5).

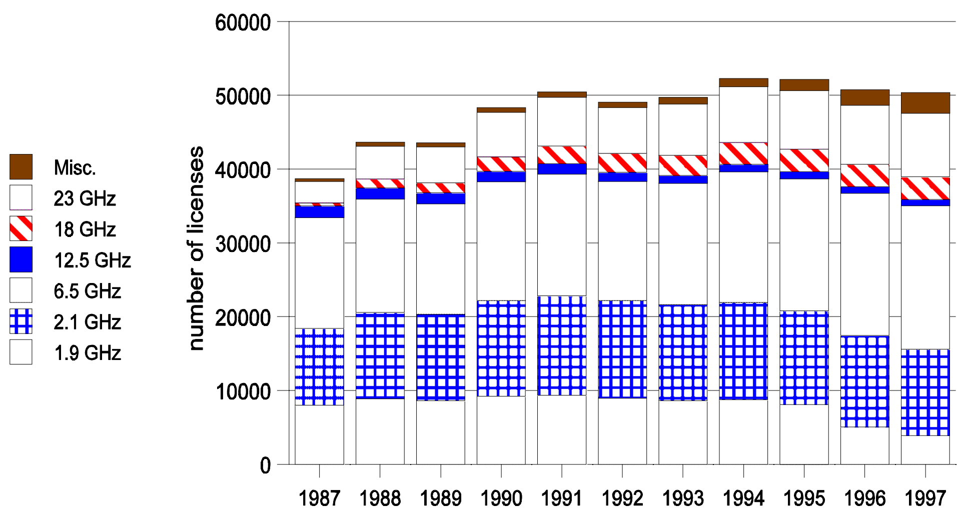

Figure 3.2. Total private licenses in the bands above 1 GHz (w/o CARS/PC).

In general, the private services grew approximately as predicted, with the forced migration from the 1.9 GHz band pushing some growth into the 6.5 GHz band and some of the higher frequency bands. Overall, the private services grew at a 1.2% annual rate between 1991 and 1994, driven mainly by the need for new licenses to provide a destination for users who would soon be displaced from the 2 GHz PCS bands. Licenses decreased at an annual rate of 1.6% between 1994 and 1997. This decrease was driven almost entirely by the decrease of users in the 1.9 GHz band, as those users were displaced by new PCS systems. Although the high level of license activity due to the 1.9 GHz migration has mostly disappeared, there were still about 1750 new private licenses coordinated in 1998.

3.3 Public Services (Common Carrier) Bands

The 1993 staff study predicted a decrease of 6% per year in the total number of common carrier licenses (Matheson [1], Table 4.4-2). Figure 3.3 shows the total common carrier licenses for bands above 1 GHz. The “Misc.” bands include 6.5 GHz, 13 GHz, and 23 GHz—all of which have relatively small numbers of common carrier licenses. This graph shows 1991 and 1997 totals of 68,375 and 74,759, respectively. This is an increase of 6384 licenses, representing an actual annual increase of 1.5%. This is a major systematic deviation from what was estimated.

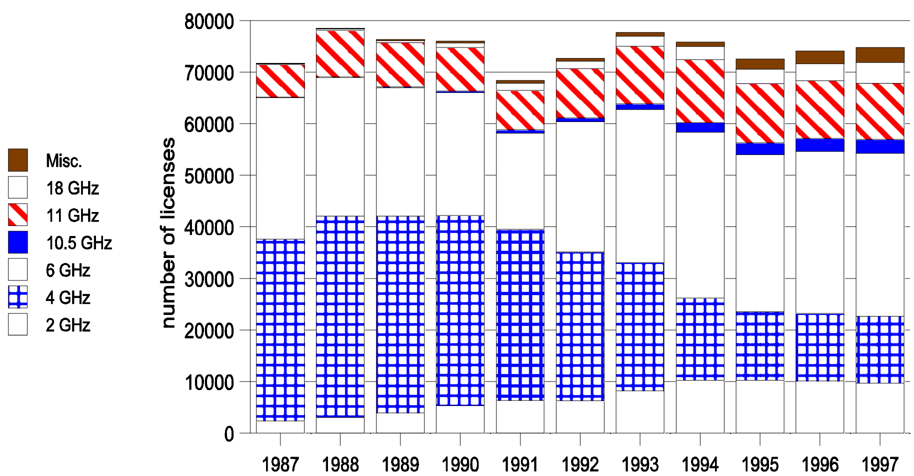

Figure 3.3. Total common carrier licenses in the bands above 1 GHz.

One might, in fairness, suggest that all of the data before 1992 pointed to the earlier conclusion. Long-term trends were consistently and strongly downward, and there was a good basis of understanding for those results. Our current understanding of what happened is as follows:

1. The telephone system continues to switch from microwave to fiber for long-distance and local connections. This trend is aided by numerous competitive fiber providers, especially in urban areas.

2. In the 1991-1994 period there was a major movement of systems from the 4 GHz band to the 6 GHz band, due to worsening problems in the 4 GHz band in coordinating with numerous satellite downlink stations. These coordination problems made it easier to place new links or any required 4 GHz system updates into the 6 GHz band. This would have been particularly easy to accomplish in some cases since the original 4 GHz hardware was also designed to operate at 6 GHz, and similar propagation characteristics in both bands generally meant that no path re-engineering was needed. Thus, many 4 GHz paths were switched to the 6 GHz band. Simultaneous with the shift from 4 GHz to 6 GHz, there was an overall long term decrease in the total number of licenses in the combined bands of about 4% per year.

The 4 GHz common carrier band declined faster than predicted, then hit a plateau around 12,000 licenses. Recent NTIA spectrum monitoring measurements in selected geographical regions [17][18][19] show the band almost completely devoid of terrestrial use, so the license data may indicate users temporarily holding unused licenses or keeping microwave networks “just in case,” rather than indicating actual use.

3. All common-carrier licenses were renewed on February 1, 1991. In a normal year, a portion of abandoned licenses remain in the records for a while until they are deleted. The dip in licenses in 1991 was caused partly by carriers updating their license applications, as required, in preparation for the beginning of a new 10-year license cycle. Thus, the 1991 dip in licenses was partly caused by clearing out previously abandoned licenses. This cycle shows up particularly in the 6 GHz and 11 GHz bands.

The problem with abandoned licenses is caused when a station is moved or re-aimed. A license is needed before the new configuration is implemented, but cancellation of the old license is not necessarily performed immediately. This problem will be worse in bands where there are many changes in network configuration, since a single station may generate an additional set of abandoned licenses every time that a site is reconfigured.

4. The cellular/PCS industry is still growing very rapidly. This growth is not merely an expansion on the periphery of an established service area, but growth is distributed throughout the system. The addition of more down-sized internal cells typically requires multiple microwave changes. These changes include reconfiguration of network topology, but they may also require adding more capacity to existing paths. The 2 GHz band and 10.5 GHz band were used to connect individual cellular sites with low capacity links, while the 6 GHz and 11 GHz bands were used to provide wideband backbone for cellular systems. This provided very strong growth in the 2 GHz , 6 GHz, and 10.5 GHz bands and moderate growth in the 11 GHz and 18 GHz bands, partially compensating for licenses lost in the shift to fiber.

One should observe that a lower percentage of cellular sites are apparently using microwave connections than in the past. With 50,000 base stations at the end of 1997, the cellular/PCS industry was identified as using only 15,000 microwave links. Although we believe that we are underestimating the number of microwave licenses used by the cellular industry, these numbers show far less than 70% of sites connected by microwave (an estimated percentage from early days of the cellular industry). Assuming a minimum of 2 licenses per site, 70% microwave usage would require 70,000 licenses–which is almost equal to the total number of all common carrier licenses (about 75,000).

The apparent “plateauing” of the number of common carrier licenses should not be mistaken for a lack of activity in the bands. In 1998, for example, some 6100 new common carrier licenses were coordinated, representing an annual “churn” of about 9% of the total number of existing licenses. The great majority of these new licenses were issued in the 6 GHz band (almost 4500 new licenses), representing a 14% churn rate in this band. This high level of activity is consistent with microwave systems being used especially to connect new or expanded activities, but later many of these microwave links are replaced with optical fiber or other technology whenever these technologies become locally and inexpensively available. On the other hand, only 14 new licenses were coordinated in the 4 GHz band, illustrating the extent of the problems in sharing this band with satellite downlinks.

3.4 Broadcast Auxiliary Service

The 1993 staff study estimated an average annual increase of 10% in the broadcast auxiliary services (Matheson [1], Table 4.5.3). Figure 3.4 shows the growth in the number of licenses for broadcast auxiliary services. Between 1991 (4923 licenses) and 1997 (8483 licenses), the number of licenses increased by 3560, giving an actual average annual percentage increase of about 9.5%, very close to the earlier estimate.

The growth during this period was controlled by two opposing trends. The television and cable industry has been growing fairly rapidly, adding whole new networks to supply programming to an increasing number of cable and broadcast chan-nels. On the other hand, the switch to digital TV (DTV) has taken longer than originally anticipated, and the details of the required changes have not been completely clear. During this period, many TV stations may have been reluctant to buy new BAS transmission equipment that would possibly be made obsolete during the switch to DTV.

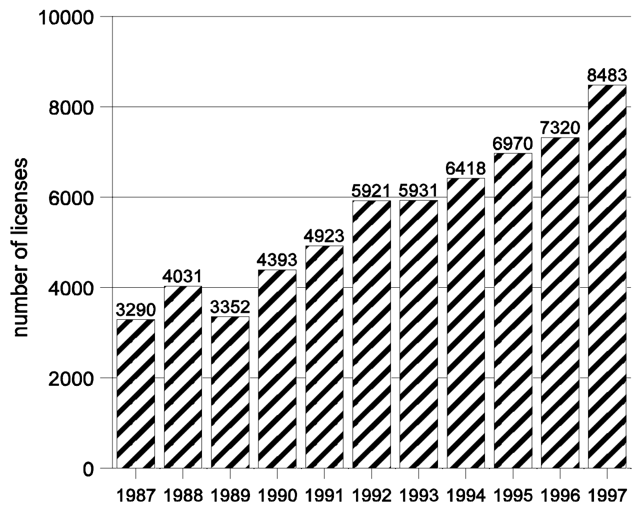

Figure 3.4. Total broadcast auxiliary licences in fixed bands above 1 GHz.

3.5 Cable TV Relay Service (CARS) and Private Cable

The 1993 staff study predicted that the 13 GHz CARS band would decrease 5% per year, averaged over the next 5 years (Matheson [1], Table 4.6-3). A more qualitative statement was that the rapid growth in this band would stop; then licenses would decrease as existing video traffic moved from CARS systems to optical fiber.

Figure 3.5 shows the license count for the 13 GHz CARS band and the private cable and CARS service in the 18 GHz band. Since these two services are technically very similar (though provided to slightly different customers), they were combined for analysis purposes. The 1991 data (107,402 licenses) and 1997 data (207,995 licenses) give an actual increase of 100,593 licenses or about 12% annual increase. These numbers show that the earlier rapid growth in the 13 GHz band paused for several years (1991-1993), then grew a little for a single year in 1994, and has decreased slightly since then. The number of licenses in the 18 GHz band, on the other hand, began growing rapidly in 1992 and has continued very rapid growth.

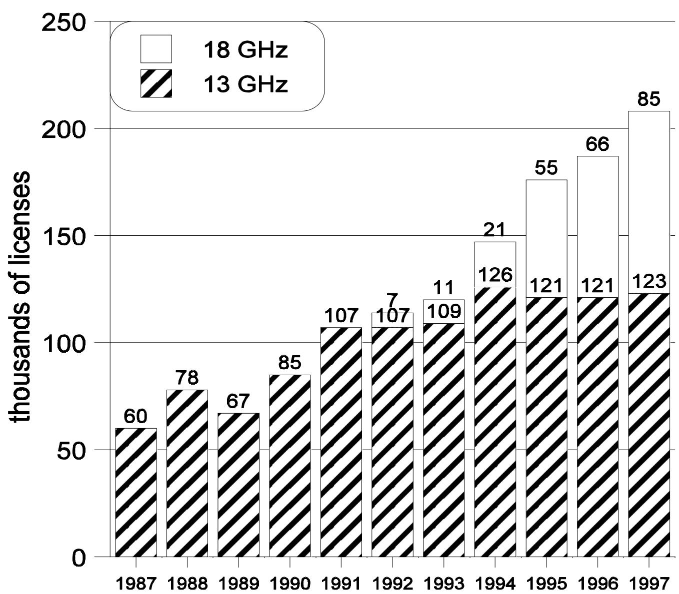

Figure 3.5. Total CARS and private cable licenses.

CARS and private cable microwave are technically and functionally almost identical, but they are controlled by different regulations, which has caused them to develop in vastly different directions. CARS was developed in the 13 GHz band to effi-ciently move large blocks of 6-MHz TV channels between a program origination point (typically a satellite downlink site) and the cable system "headend" sites. A similar block of contiguous 6-MHz channels was also created in the 18 GHz band for use by CARS or private cable operators. CATV headends convert the CARS signal to a signal in the cable, and the signal is transferred through an elaborate network of cables, amplifiers, and splitters to individual customers (usually private homes or apartments). CARS is considered part of the CATV system, whose cable connections spread across every public roadway where houses are built.

Beginning around 1991, CATV operators began "remodeling" their cable networks to allow more channels and future digital services. This remodeling broke up the single coaxial network into many smaller coaxial networks (typically each covering1000 homes) connected together with optical fiber. The smaller coaxial networks allowed an expansion of system bandwidth from around 300 MHz to as much as 750 MHz, providing more channels and the possibility of individualized two-way services to each customer. Initially, the remodeling was used mainly for additional TV channels, but recently many cable systems have begun to offer a wide variety of two-way digital services, including digital TV channels, high-speed cable modems, and telephony. The proposed AT&T/TCI merger is aimed directly at large-scale implementation of two-way digital cable services.

In many current cable systems, including most urban systems, optical fiber networks have mostly replaced the use of CARS microwave links. In some cable systems, especially rural cable systems, some additional CARS channels were needed to fill the wider cable bandwidths. The net effect of these changes is that a large number of CARS channels have been taken out of daily service, even though the CARS license information in Figure 3.5 does not reflect those changes. Accurate information on the number of CARS licenses actually in use is not available for this report.

Private cable relay service at 18 GHz provides a function identical to CARS, except that private cable customers are in large hotels or apartment complexes. Private cable microwave signals are sent directly to each individual building where the operator intends to provide services (i.e., each building acts as a headend site). The signals are distributed throughout the building or campus via coaxial cables, but the cables are not allowed to cross a public right-of-way. By remaining "private" the private cable operator escapes many regulatory obligations, including "must-carry" rules, local franchise agreements, and many more. Moreover, the private cable operator is able to serve very large customers, while avoiding the expense of building and maintaining an elaborate city-wide cable network. As with CARS, private cable microwave requires a license for each channel at each destination. However, private cable must treat each building as a separate destination. Thus, a single private cable hub might have as many as 2000 licences (72 channels to each of 30 buildings). These factors have driven (and will continue to drive) the very rapid growth of private cable microwave systems.

As a result of serving only individual buildings, as well as being forbidden to cross public right-of-ways, private cable has not developed any associated wide-area fiber optic networks. Therefore, at a time when CATV is abandoning its CARS system in favor of large multipurpose optical fiber networks, private cable at 18 GHz is still rapidly expanding its microwave distribution network. The lack of a fiber network to support wideband two-way digital services in future private cable systems may present future growth problems, especially since the large building complexes served by private cable are also especially targeted by other competitive access providers (CAPs). In the future, in buildings served with fiber, private cable services might be provided more economically via fiber. In buildings not served with fiber, microwave delivery of private cable services might be economical, but delivery of 2-way digital services will be strongly contested by other wireless access providers. Future development also depends crucially on future regulatory decisions, including the degree to which private cable signals can cross public right-of-ways in fiber belonging to someone else, the amount of common carrier-like traffic that can be carried on "private" systems, the possible imposition of more regulations, and the availability of other frequency bands to replace 18 GHz spectrum lost to satellite systems.

In summary, earlier predictions of CARS license decreases in the 13 GHz band were in error partly because cable operators have not yet returned unused CARS licenses and partly because of the need to distribute additional video programming to fill wider-bandwidth cable systems. The rapid growth in the 18 GHz band was mainly caused by the growth of a new service (private cable relay) and (to a lesser degree) by the need to fill the new wider-bandwidth cable systems. At the time of the earlier staff study, 18 GHz private cable was just starting up, and its future growth was completely overlooked by that study.

3.6 Summary

The license counts in private, broadcast auxiliary, and Federal Government services changed about as predicted. Figure 3.6 summarizes growth in the major microwave service categories, not counting CARS and Private Cable transport. Data on Federal fixed-only assignments were not available for the years before 1991. Noteworthy departures from predictions came from the 18-GHz private cable service, and the 2-GHz, 6-GHz, and 11-GHz common carrier bands. In all cases, these microwave bands grew more rapidly than anticipated or did not shrink as predicted. The total number of licenses associated with these services reached a high point in 1994 and has been approximately constant since then.

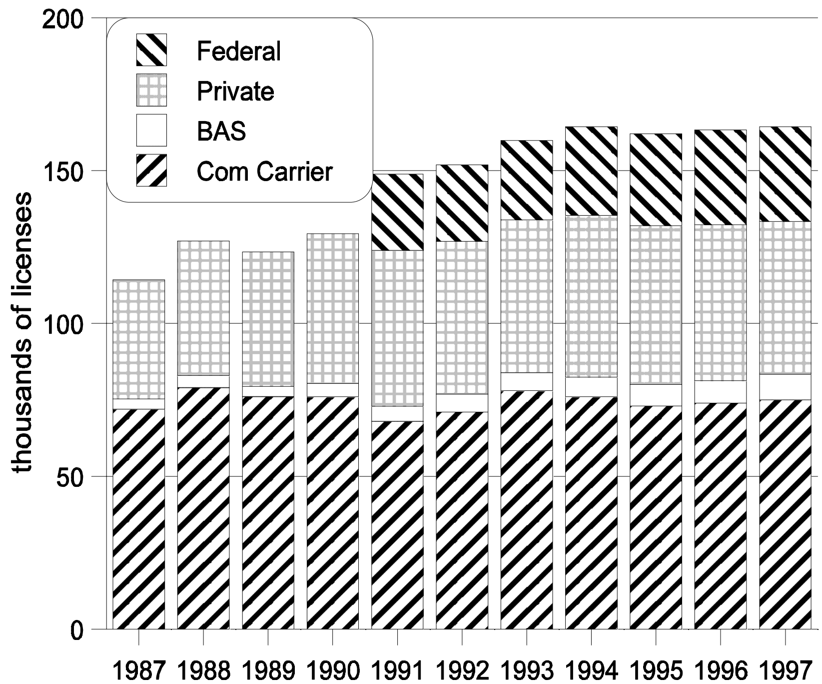

Figure 3.6. Summary of fixed service licenses, not counting CARS/private cable.

The growth of CARS and private cable in the 13 GHz and 18 GHz bands (shown in figure 3.5) is not included in figure 3.6. These services have grown very rapidly, reaching 207,000 licenses in 1998, with growth apparently continuing at a rate in excess of 10% annually. Although the number of licenses in CARS and private cable exceeds the total number of licenses in all of the other fixed services, the large number of CARS licenses at 13 GHz is quite misleading, since many of these licenses are no longer in use. Nevertheless, the private cable service at 18 GHz continues to grow very rapidly, unlike most of the rest of the fixed services.

None of these microwave license counts include the use of unlicensed terrestrial links implemented in the ISM bands using spread-spectrum technology and Part 15 rules. It is believed that 20,000 unlicensed microwave point-to-point links have been installed for private and common carrier operations, mainly in the 2.4 GHz and 5.8 GHz ISM bands. We note that one manufacturer suggests initially installing an unlicensed link at 5.8 GHz and deciding later whether to change it to licensed operation in the 6 GHz or 6.5 GHz bands.

Likewise, we are unable to collect current data in any of the rapidly-growing bands where area-wide geographical licenses are granted, such as the 24 GHz and 39 GHz bands. For example, Winstar claimed to have installed almost 200,000 lines by June 1998. Assuming that a third of these were installed with T1 microwave links (28 lines per link), these lines would represent about 2100 new links (equivalent to 4200 licenses) in the 39 GHz band alone.

The significance of the preceding two paragraphs is that some major growth trends may be invisible to our data-gathering processes. If the stated assumptions are correct (not necessarily so), the number of microwave links has been continuing to grow, instead of leveling off as indicated by license counts. However, we also believe that some microwave license counts are inflated by unused links (especially at 4 GHz and 13 GHz) and churn in the cellular/PCS bands, and we believe that the newer microwave links tend to be lower-capacity and shorter-range links than were traditionally built (especially in the common carrier service). Therefore, the present population count of licensed microwave links may represent less spectrum use and less investment than earlier populations, but it may also miss an increasing number of links that are not individually licensed.

4. PREDICTIONS FOR FUTURE USAGE

Predictions of usage on a band-by-band basis are particularly problematic now. The rechannelization and private and public sharing of most of the bands has introduced new factors that destroy some of the relevance of band-by-band historical data. The further blurring of distinctions between private and public carriers, between cable TV operators and LECs, between CARS and private cable relay systems, and even between fixed and mobile services under the "wireless" label may cause difficulties in identifying the general industrial categories into which future predicted operations should be placed. Finally, the expanded use of equipment that is not individually licensed (because of geographical area licensing or the use of non-licensed bands) may make license databases less useful as a source of information. Nevertheless, the following general predictions can be made.

4.1 Federal Government

Federal Government use of fixed services will remain approximately constant. Factors decreasing the number of Federal assignments include a general downsizing of many Federal Government facilities (especially military facilities) and the continually improving capability of commercial communications to meet present and future Federal needs. These will cause a slow continued shift of non-military telecommunication services from agency-owned networks to commercial services. On the other hand, Federal use of communications and the associated information technologies will continue to grow substantially, in many diverse activities. In particular, military use of communications and information technologies as a “force multiplier” will tend to increase military communication requirements generally, including military use of fixed services. Moreover, military communications tend to have requirements which are quite different from those of many commercial users (and, thus, not easily converted to commercial services). Overall, it is expected that Federal fixed service assignments will remain constant over the next 5 years.

4.2 Private Operational Use

Private microwave licenses will decrease in the frequency bands below 6 GHz and increase in the bands above 6 GHz. The decrease in the lower frequency bands will be driven by the need to vacate the 2 GHz

PCS bands, including the bands in the 2110-2200 MHz range. Some of the growth in the higher frequency bands will be migration from the 2 GHz bands, but much will be a continuing slow expansion of the traditional private microwave services to industry and government. The private microwave service is expected to show no net annual growth over the next five years. Private cable systems are not included in this estimate.

Since BSS services have finally been established in the 12.2-12.7 GHz band, there may be an accelerated departure of old microwave users from that band. Since the 4 GHz, 6 GHz, and 11 GHz common carrier bands, with bandwidths up to 40 MHz, are now available for private use, there may be new opportunities for private companies to establish wideband internal microwave services.

The rapid recent growth of microwave services intended to support private cable TV systems will continue for a few years. After a few years, however, it will face considerable competition from other forms of video distribution, especially two-way urban fiber networks designed to provide two-way broadband services.

Private microwave services used to bypass LEC's over relatively long distances may be somewhat diminished by very competitive services provided by fiber-based or microwave-based competitive access providers acting as common carriers. Narrowband and remote SCADA applications will meet increased competition from new low-cost satellite and PCS wireless-data applications.

It is predicted that there will be very substantial growth of fixed microwave systems in WLANs and similar home-based or business-based private communication systems in the future, but much of this growth will not be licensed and cannot be included in estimates based on the number of licensed systems. Instead, this growth will be accomplished under Part 15, ISM, unlicensed PCS, or U-NII rules.

4.3 Common Carrier Services

Common carrier microwave licenses will continue net growth, but this net growth will be the result of several divergent trends. Common carrier traffic will continue to expand rapidly. However, a continually larger proportion of common carrier communications will be carried on optical fiber. Microwave links will continue to be valuable for rapidly growing systems and are expected to continue to have extensive application in cellular and PCS industries. New fixed microwave applications, including WLL, ILEC bypass, and other high-density fixed services (HDFS) may greatly expand the use of higher-frequency microwave bands for short range links to access individual customers. Some of these trends might be difficult to track, especially since many of these short-range links will not be individually licensed.

The number of licenses in the 2 GHz band will begin to drop rapidly when future details on the use of the remainder of those frequencies are determined and the bands must be vacated to make room for new PCS and satellite services. Until then, however, there will be continued 2-GHz support of cellular/PCS systems. The role of the 2.3 GHz WCS bands is currently unknown; possibly they will become a migration destination for displaced 2-GHz fixed systems, upstream links for two-way digital MMDS, or audio satellite broadcasting. The migration out of the 4 GHz band will continue. Although the future role of backyard TVRO systems as a "spoiler" for the 4 GHz band seems likely to diminish somewhat (because competition from 12-GHz BSS systems is reducing the number of 4-GHz TVROs), severe problems with licensed satellite downlinks will continue.

Cellular and PCS operations will move strongly into the bands above 10 GHz, with growth expected specifically in the 10.5 GHz, 11 GHz, 18 GHz and 39 GHz bands. Much growth is expected in bands that were previously limited to private services, particularly since these bands have the majority of the narrower channelization plans. The original common carrier bands, especially 6 and 11 GHz, will tend to be used especially for longer range, wideband, high-traffic requirements. Though it is evident that there will be major activity in all common carrier bands, it is not yet clear how the future cellular and PCS backbone infrastructure will be shared between microwave, copper, and fiber technologies.

Rates at which some of the new HDFS technologies will be developed remain subject to uncertainty, but these new technologies will probably drive huge growth in microwave markets. Broadband WLL (24 GHz) and wireless fiber (38 GHz) are common carrier technologies that could be very successful. In addition, LMDS and MMDS may grow rapidly in the near future and may carry substantial amounts of two-way traffic (telephone and Internet services) to its subscribers. The reader should recognize that these new technologies represent a fundamental shift in the use of microwaves by common carriers to provide "access" to customers, instead of using microwaves mainly for internal signal transport. It is expected that the growth of licenses in some of these new services may not be useful in tracking the number of transmitters, since the transmitters will usually not be individually licensed.

Not counting licenses used for individual consumer access in the new systems (a reasonable assumption, since most of these applications will not be individually licensed), it is expected that traditional common carrier licenses will increase by 1% annually. However, there will be much growth in common carrier services that are not individually licensed.

It is not completely clear what criteria should be used to track future common carrier microwave growth, even if the data were available. Although it would be very useful to have data available on the number of nonlicensed transmitters, other problems would still remain. For example, many of the new systems that will be used in the 24 GHz, 28 GHz, and 39 GHz bands may use adaptive point-to-multipoint architectures. These systems might continually adjust the bandwidth and direction of radio "beams" from a hub site, depending on the instantaneous traffic requirements of individual users. How should the capacity of such hubs be compared in a meaningful way to a traditional point-to-point link? Does a short-range indoor WLL link (e.g., a cordless phone supplied by the LEC) count the same as a 30-km DS-3 path? The question is not merely academic, since answers are needed before one can choose useful growth criteria that can form the basis for a prediction of growth. This problem is particularly vexing in the rapidly-changing common carrier environment.

4.4 Broadcast Auxiliary Services

Broadcast auxiliary licenses will increase, based on the need to provide more local video coverage and to support a variety of HDTV, SDTV, and conventional TV programming. This does not necessarily mean that additional spectrum will be needed, however, since digital compression techniques will allow the existing ENG wideband analog FM channels (currently 15-25 MHz bandwidth) to be narrowed, doubling or tripling the number of channels from the current spectrum. There will be a massive adjustment in STL systems when broadcasters convert their systems to the new digital technologies and begin to support multiple channels and non-video formats. Existing analog FM STLs can be replaced with single digital STLs carrying digitized NTSC and HDTV signals. Some broadcasters will use this transition as an opportunity to switch microwave STLs to fiber, possibly in cooperation with other broadcasters using shared broadcasting/tower facilities. Over the long run, continually more fixed functions like STLs will be carried on fiber. It is predicted that total broadcast auxiliary licenses will increase 5% annually over the next 5 years.

4.5 CARS and Private Cable

CARS licenses will decrease substantially over the next 5 years, following the conversion of many cable systems to digital fiber systems utilizing two-way architectures. This decrease was predicted to have begun already, but cable operators have been slower than expected in converting to two-way digital systems. Moreover, following system conversion, operators have not been quick to turn in unused licenses, so that the 123,000 CARS licenses shown in Figure 2.27-3 overstate the number of licenses in actual daily use.

At this time, large MSOs are aggressively building two-way networks and are beginning to deploy some advanced cable services, such as high-speed cable modems for Internet access. The proposed TCI/AT&T merger is based on a widespread and rapid implementation of a 2-way digital cable network providing a full range of advanced cable services. Urban cable systems should be mostly converted to two-way architectures before the end of 1999, with rural systems lagging by several years. It is difficult to understand what functions (if any) CARS will provide in the new two-way digital cable systems. Nevertheless, the existing CARS systems still represent a wireless plant of extremely wide bandwidth communications capacity, albeit one-way only, located in the heart of many urban areas. That might be something useful.

Private cable microwave will continue to grow for a few years at a 10% annual growth, depending partly on continued favorable regulatory decisions. The prospect of long term continued growth is less certain. More than half of the 18-GHz private cable spectrum has been proposed for reallocation to satellite services on a primary basis, jeopardizing the spectrum used for future private cable systems. In addition, the multiple dwelling unit (MDU) customers served by private cable will also be early targets for many other fiercely competitive new technologies, including fiber, CATV, BSS, MMDS, LMDS, 24 GHz, and 39 GHz.

4.6 HDFS and Non-traditional Fixed Services

A number of new fixed services will assume prominence in the next 5 years, including some of the proposed high density fixed services (HDFS). Although these services nominally might be included in the common carriers designation (Section 4.4), we have included these services in a separate new category. Wireless local loop services will begin to be provided in the 24 GHz band, as well as other DEMS services such as WLANs. These services may grow very rapidly, made possible by new technologies for manufacturing higher frequency semiconductor devices. However, depending how these services are licensed (e.g. by geographical area), it may be useless to try to track their growth by merely counting the number of area-wide licenses auctioned.

The 39 GHz band is growing rapidly, mainly based on Winstar's deployment of their "wireless fiber" network. This growth will be accelerated following auctions that will distribute many additional BTA-wide licenses to other users, especially if the Winstar business plan is successful.

LMDS will be widely deployed in the 28/31 GHz band, beginning in urban areas. This service will provide broadband data and (only in some cases) video entertainment. Similar services will be provided in rural areas using a two-way digital version of MMDS. Unlicensed point-to-point and WLAN services will continue to grow rapidly in the 2.4 GHz and 5.8 GHz ISM bands, the 5 GHz U-NII band, and possibly in the newly allocated 59-64 GHz unlicensed band. Short-range in-home or in-office wireless computer interconnection and home appliance interconnection may become popular—presumably in the ISM bands or in the unlicensed PCS and U-NII bands.

It is difficult to know whether all (or any) of these applications will be commercially successful (and, if they are successful, whether to count them as part of the traditional fixed services in the next fixed services report). Not only are these totally new applications, but they are still changing. MMDS and LMDS, for example, started out as alternative ways to distribute analog TV. They are now becoming super-CLECs, offering telephone, high-speed Internet access, and video entertainment. Who knows what they will be ten years from now? Industry is making its predictions backed with billions of dollars of capital investment. The author hesitates even to venture a guess, but it will be very interesting to see how things work out.

4.8 Summary of Predictions

The future use of traditional microwave systems will be squeezed into niche markets representing a continuously smaller percentage of a continuously larger total telecommunications market. At present, these opposing trends have approximately balanced out, resulting in fairly stable net use of licensed microwave communications. Similar results are expected for the next five years, with predictions for the more distant future becoming more uncertain (with approximately equal portions of optimism or pessimism).

Although the traditional niche markets are expected to show little net growth, they will continue to provide very important services that have few obvious alternatives. The long-range low-density applications, suitable for SCADA or to bring communications to smaller remote communities, will remain crucial to areas not served by other suitable media. Microwave will continue to have deployment advantages in areas where terrain (including the very complex and expensive urban terrain) causes problems for installation of copper and fiber cables. The ability to use microwave systems to bring instant connectivity to rapidly changing cellular/PCS systems (as well as other short-term scheduled and emergency uses) will remain a major microwave advantage over competing technologies. Finally, microwaves will continue to be used for high-reliability, earthquake- and backhoe-proof critical circuits. However, the continued massive installation of additional fiber by LECs, CLECs and CAPs, the deployment of wideband two-way digital cable systems, the new availability of narrowband and wideband satellite systems, and the continued development of wireline pair-gain technologies (e.g., xDSL) will continue to erode the geographical areas and the specific applications where microwave technology is the only obvious choice.

Although the continuing requirements for the traditional microwave transport applications will probably not increase significantly, there may be rapid growth of several new microwave applications. These fast-growing applications include many HDFS and short-range access applications, operating in the higher frequency bands where smaller antennas and wider bandwidths are fortuitously available. These applications will tend to serve individual users and small groups of users—often with nonlicensed, mass-marketed equipment. These applications are associated with acronyms like WLL, MMDS, LMDS, FWA, U-NII, WLAN, and more. It is too early to predict which of these systems will become significant components of a future microwave industry, though many of these applications are being aggressively developed at the present time. Some of these new applications may form the basis for future ubiquitous microwave systems, deployed on a scale that is barely imaginable today.

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